An integrated approach for produced water treatment using sand filtration activated carbon and microemulsions modified activated carbon

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Abstract

In this study, the physical and chemical characterization of produced water was done followed by treatment through sand filtration coupled with activated carbon and microemulsion modified activated carbon techniques. The results of characterization showed that the produced water had high chemical oxygen demand (COD), and total organic carbon (TOC) values as high concentration of (BTEX) and various metals. After the sand filtration, considerable reduction in TSS and COD was achieved. Furthermore, BTEX were also removed by more than 93% except for toluene. However, sand filtration was not enough to remove most of the metals and ions. Therefore, further treatment was done through activated carbon and modified activated carbon and their treatment efficiency was compared. Both techniques were able to achieve higher removal efficiencies for BTEX, metals and ions. Thus, the treated water was free from all major pollutants of produced water and can be considered suitable for reuse at industrial or domestic level.

Introduction

In oil and gas industry, produced water is considered as the largest waste stream which contains relatively higher concentration of hydrocarbons, heavy metals and other pollutants. Due to the increase in industrial production and activities, the generation of produced water has increased all over the world and its treatment for reuse is now important from environmental perspective.

The produced water from natural gas production process in the Qatari North field offshore considered largest volume of wastewater in Qatar, which could be considered a potential benefits source for the industry as well as for other domestic uses if it was treated properly, taking into consideration economical cost and conditions aspects.

Objectives

The main aim of this research is to study the physical and chemical characterizations of the produced water associated with natural gas production from the North Field in State of Qatar and examine the removal of various heavy metals and inorganic pollutants from the produced water by using different treatments techniques such as sand filter, activated carbon and modified activated carbons (Microemulsions techniques).

Methodology

Produced water sampling:

Produced water samples were collected from north offshore gas field over the time period of 10 days , 200 liters of produced water was collected and mixed and considered as representative of produced samples.

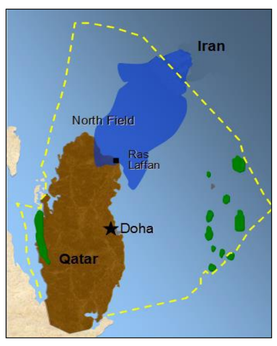

Figure1: Map sampling location sites in Ras Laffan industrial city.
Figure 2: 200 liters of produced water was collected and mixed for 10 days .

Sand filtration column preparation:

Sand filtration column was prepared with a combination of sand and 2% clay. The 8 polyvinyl chloride (PVC) columns were prepared as shown in (Fig. 3) , the sand filtration was done at a flow rate of 0.3m3/h.

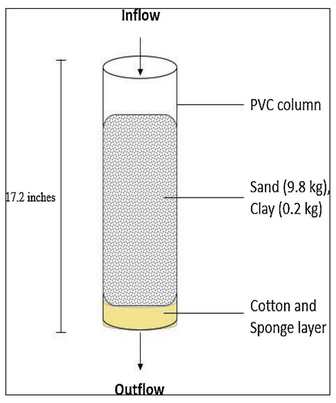

Figure 3: Schematic of the sand filter column.

Figure 4: Sand filtration stage with Millipore water followed by produced water , collecting 4 controls samples and 4 samples.

Activated carbon filtration column preparation:

The glass columns were filled with 100 g of prewashed & dried activated carbon. The filtered water from sand filtration column (stage 1) was used as feed water for activated carbon filtration.

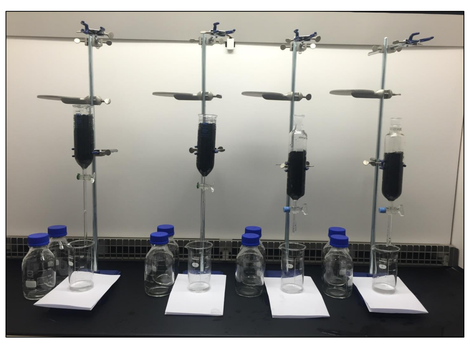

Figure5: Activated carbon filtration columns.

Modified activated carbon filtration column preparation:

Activated carbon was mixed with surfactant Triton X-100 (non-ionic) and shacked for 6 h , The glass columns were filled with 100 g of MAC . The filtered water from sand filtration column (stage 1) was used as feed water for modified activated carbon filtration.

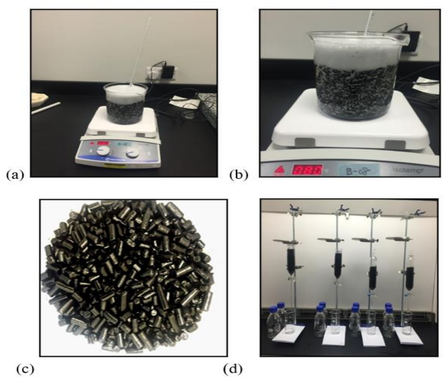

Figure 6: (a), (b) preparation of Micro-emulsion, (c) Modified activated carbon (d) filtration columns with MAC.

Results &Discussions

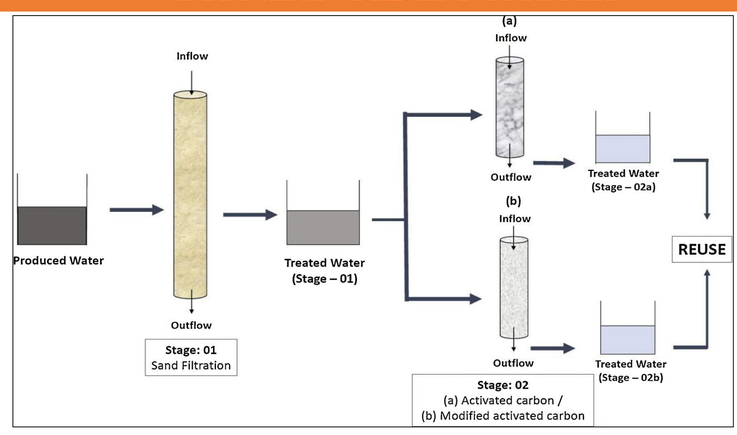

Figure.7 Treatment of produced water through combination of sand filtration and AC and MAC.

Produced water characterization:

- PW is acidic in nature with mean pH value 4.43 .
- The mean conductivity value was found to be 7035 µS/cm.
- The results of BTEX ; benzene was (11,170 ppb), ethylbenzene (4648.6 ppb), xylenes (1156.8 ppb) and toluene (378.1 ppb).
- The most abundant metals and cations found were sodium (1198 mg/l), potassium (100.9 mg/l), calcium (285 mg/l), and magnesium (45 mg/l)
- The total organic carbon (TOC) was 2405.6 mg/l, while the COD and BOD were found to be 10496.6 and 1034 mg/l respectively.
- The oil and grease content in PW was 40.5 mg/l.

Treatment of produced water:

Sand filtration (stage - 1):

Sand filtration showed higher removal efficiency for the flowing parameters:

- Total suspended solid (TSS) by 77.5%.
- Oil & grease by 97%
- Total Nitrogen by 63.7%.
- Corrosion inhibitor 94.1%.
- Chemical oxygen Demand COD by 10.2 %.
- B.T.E.X it showed high removal efficiency more than 95% except for the Toluene was 26.7%
- The highest metals removal efficiency is for the Iron, Chromium and Manganese, >99%, 97.5 % and 95 % respectively.

Figure 8: Produced water (PW) before and after sand filtration (SF)

Activated Carbon Filtration (stage – 2a):

Activated carbon filtration showed higher removal efficiency for the flowing parameters:

- Chemical oxygen Demand COD by 23.7% .
- Total organic compound TOC 30.7% .
- Organic acid was the highest for the acetate and propionate with 83.6% and 88.7% respectively.
- Phosphate by 94.9%.
- Highest removal efficiency more than 97% for the B.T.E.X except for the Ethyl benzene was 76.9%.
- Some metals such as Zinc, Copper, Boron, Nickel, Iron and chromium.

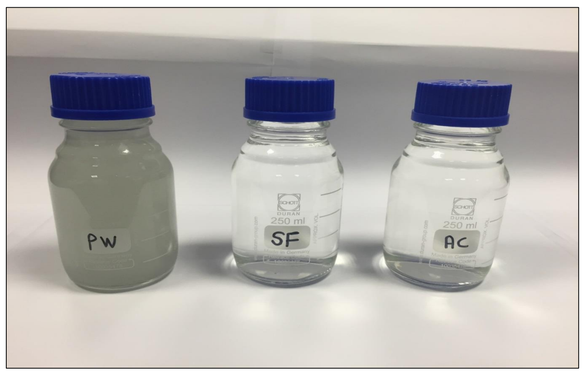

Figure 9: Treated water after the activated carbon filtration (AC)

Modified activated carbon (stage-2b)

Modified Activated carbon filtration showed higher removal efficiency for the flowing parameters:

- More efficient to reduce the TOC with 31.1%.
- Phosphate and Sulphate by 94.9 and 48.4% respectively.
- B.T.E.X removal efficiency is like AC more than 98% except for the Ethyl benzene was 92.3% higher than AC 76.9%.
- MAC was more efficient than the AC to reduce the zinc, molybdenum and Boron concentration and less efficient than AC to reduce copper.
- MAC is less efficient than AC to reduce the acetate (Organic acid).
- COD concentration increased by 12.6%.

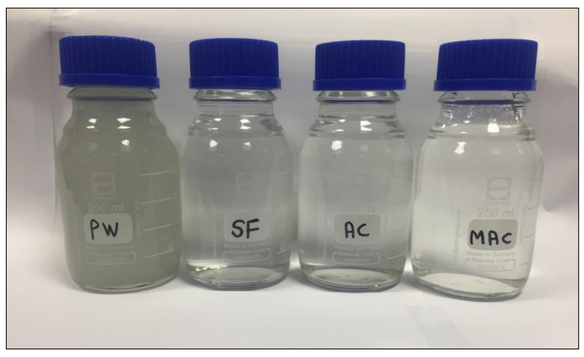

Figure 10: Treated water After the modified activated carbon filtration

Conclusion

- Chemical and physical composition of the produced water showed that the produced water contains variety of pollutants including BTEX and metals at high concentrations.
- Sand filtration showed higher removal efficiency for TSS (77.5%), and corrosion inhibitors (94.1%) which is attributed to the straining mechanisms. The highest metals removal was for iron and manganese and was also able to remove BTEX. However, the COD removal efficiency after sand filtration was only 10.2% and therefore, further treatment with activated carbon or modified activated carbon was necessary to ensure reuse of produced water.
- Both activated carbon and modified activated carbon techniques were able to achieve high removal efficiencies; 100% removal was achieved for most of the metals and more than 95% removal was obtained for BTEX.

Acknowledgement

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