Oilfield Produced Water Management: Treatment, Reuse and Disposal

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Abstract :

Produced water is accompanied with the production of oil and gas especially at the fields producing by water drive or water injection. The quantity of these waters is expected to be more complicated problem with an increasing in water cut which is expected to be 3-8 barrels water/produced barrel oil.

Produced water may contain many constituents based on what is present in the subsurface at a particular location. Produced water contains dissolved solids and hydrocarbons (dissolved and suspended) and oxygen depletion. The most common dissolved solid is salt with concentrations range between a few parts per thousand to hundreds parts per thousand. In addition to salt, many produced waters also contain high levels of heavy metals like zinc, barium, chromium, lead, nickel, uranium, vanadium and low levels of naturally occurring radioactive materials (NORM).

This study will highlight the main aspects of the different international experiences with the produced water treatment for subsequent reuse or disposal. These different treatment methods vary considerably in effectiveness, cost and their environmental impacts. Samples of produced water from Al-Mishrif formation in ten wells belongs to five fields southern Iraq were taken and analyzed chemically to define the basic features of these waters and to have guide lines for the best strategy that required handling the increased water cut in these fields.

Key words: produced water,treatment,reuse,heavy metals

Introduction:

Produced water may be stored on the surface in open pits, which can be considered as evaporation pits or disposal pits. It contains many constituents based on what is present in the subsurface at a particular location. It may contain salt, volatile organic compounds, polycyclic aromatic hydrocarbons, heavy metals and naturally occurring radioactive materials [1]. In addition to naturally occurring impurities, chemical additives like coagulants, corrosion inhibitors, emulsion breakers, biocides, dispersants, paraffin control agents, and scale inhibitors are often added to alter the chemistry of produced water [2].

The study of chemical analysis of the produced water is important because it helps in studying the nature of its aquifers and it is also important in the operations of injection and recovery of wells especially the analysis looking for ions involved in the installation of the water. In addition, the widespread use of water in the secondary extraction of oil has given a large importance to the water where the injected water in the lower layers of the configurations provide the energy

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required to produce the equivalent of half the size of the located oil.

A number of methods are available to treat contaminated water to prepare it for reuse or disposal [3,4,5,6,7,8,9,10]. These methods vary considerably in effectiveness and cost.

Generally, the contaminants in water of petroleum industry can be classified into two groups: hydrocarbons and solids with two phases for each group suspended and dissolved.

In this study, many methods have been discussed for their advantages in produced water treatment prior to reuse in different activities at locations or to responsible disposal. The different methods are divided according to mentioned state of contaminants. Samples of produced water were collected from ten wells at south of Iraq and analyzed for their brine composition and concentration of some heavy metals.

Treatment Methods :

As mentioned before and for the purpose of this study, the treatment methods would be classified into the following categories:

I. Removal of Suspended and Dissolved Hydrocarbons

A variety of methods are available to remove suspended oil droplets from water which consist primarily of gravitational separation, filtration, or biological degradation. Gravity separation which done normally in separator tanks is usually the simplest and almost economical way to remove large quantities of frees oil from water. The effectiveness of separation tanks depends on the droplets size and how long been the water in the tank [11, 12]. Several different designs of separation have been developed to use centrifugal forces to enhance phase separation. Hydrocyclones and centrifuges are other types of gravitational separation devices. The effectiveness of hydrocyclones in separation process depends on a number of parameters including oil droplet size, oil/water density difference, inlet water velocity, solution gas, solids, and system geometry [13, 14].

Another way to remove oil droplets from water is using water-wet filters or membranes in a process called filtration. Advanced filtration processes include cross flow membranes such as microfiltration and ultrafiltration [15]. Oil-wet filters is another type of filtration in which sand, gravel, or glass fibers are common media used in this process [15]. Generally the filter design is based on water quality specifications.

Biological processes which used microorganisms (bacteria and/or fungi) in degradation of hydrocarbons have been widely used to treat most wastewater streams in the petroleum industry. Moreover, different processes such as heater treating, gas flotation, chemical and electric field separation can be added to above methods.

Many methods are available to remove the dissolved hydrocarbons from water include adsorption, volatilization, oxidation, ultraviolet irradiation, precipitation, and biological processes [16, 17].

Adsorption of dissolved hydrocarbons onto a solid medium is an effective way comparing with other methods. Also, coal, natural and synthetic resins have been proved their effectiveness as solid medium [17]. Volatile organic carbon compounds (VOCs) can be removed from water by lowering the partial pressure of the compound in the vapor in contact with the water [2]. Air stripping and steam are two types of

volatilization methods. By lowering the PH, some organic materials not all can be precipitated. In ultraviolet irradiation, high energy, short – wavelength photons are used to break the chemical bonds of dissolved hydrocarbons[18].

Ozone, Peroxide, chlorine have been tested to destroy dissolved hydrocarbons through a process called oxidation [18].

Biological treatment using a mixture of oxygen and nutrients with the water can be useful to remove low levels of dissolved hydrocarbons from water.

II. Removal of Suspended and Dissolved Solids

The resulted suspended solids during drilling and production activities include cuttings, sand and clay particles. Several methods are available for removing the suspended solids from the water among of them filtration, coagulation and gravity separation.

Filtration has considered as promise method for separating water oilfield [19]. An effective way to enhance the separation of suspended particles is to coagulate (flocculate) the particles by adding chemicals like calcium chloride, ferric chloride, or aluminum potassium sulfate, into large agglomerate [20]. Then one of the processes like filtration, gravitational setting or centrifugation can be used to separate these larger agglomerate from water.

The dissolved solids include salt, hardness ions (calcium and magnesium), and heavy metals. Processes like ion exchange, precipitation, evaporation/distillation and biological treatment are examples of known options in treating such contamination.

The removal of harness ions is very necessary because these ions readily precipitate and form a hard scale that can affect the equipment work. In general, there are two major ion exchange resins (substrates) which are commonly used: strong acid resins using sulfuric acid, and weak acid resins using carboxylic acid [2]. Adding lime $Ca(OH)_2$ or sodium hydroxide (NaOH) result in an increasing in PH of the water and lead to enhance the precipitation of many dissolved solids [21].

Evaporation and distillation the water need a stream of pure water, so they considered an expensive method.

Biological processes can not destroy dissolved solids, but they can alter their chemical form as well as removing sulfides from produced water [16,22].

III. New Technologies in Produced Water Treatment

Membranes represent one of the effective techniques in the primary treatment for water such as micron membranes, or in secondary treatment as desalination with reverse osmosis. Membranes suffer when they are used for treatment of surface water or ground water from numerous problems, including the deposition of poorly soluble salts in the water on it, as well as by the deposition of plankton and the phenomenon of concentration polarization which lead to increased pressure difference across the membrane. These problems are exacerbated with the associated water extraction of oil, leading to the need for an elementary processor complex and expensive before entering the water to the membrane. Some company's specialized partial solution to the problem and the production of membranes that bear the harsh operating conditions. The new

membrane system is known as VSEP which is an acronym for vibratory shear enhanced process. The results of this technology have demonstrated many advantages when compared with other conventional cross flow filtration techniques and other methods of treatment [23].

Table (1) represents the results using VSEP membrane filtration [23]. Also, it indicates that the choice of membrane would depend on the filtrate quality desired. It can be seen, that reverse osmosis (RO) membrane gave best filtration in comparing with nanofiltration (NF) filtration.

Table 1 : Results using VSEP membrane filtration.[23]

Typical VSEP Results	Untreated	NF Filtrate	RO Filtrate
Total Organic Carbon (TOC)	810mg/L	120mg/L	20mg/L
Total Suspended Solids (TSS)	9000 mg/L	ND	ND
Chemical Oxygen Demand (COD)	2600 mg/L	270 mg/L	71 mg/L
Oil and Grease	580 mg/L	16 mg/L	ND
Chlorides (Cl)	4700 mg/L	2900 mg/L	15 mg/L
Sulfates (SO_2)	210 mg/L	ND	ND
Calcium (Ca)	400 mg/L	8 mg/L	ND
Magnesium (Mg)	50 mg/L	ND	ND
Zinc (Zn)	100 mg/L	5	ND
ND = Not Defined			

Also, sorption of organics by surfactant-modified zeolite (SMZ) followed by air stripping and subsequent treatment of the off-gas by vapor-phase bioreactor (VPB) has been shown to effective at removing benzene, toluene, ethylbenzen, and xylene (BTEX) from produced water [23-24].

Results and Discussion:

Brine composition and concentration of some heavy metals in produced water from ten wells (south of Iraq) are summarized in Table 2. Also, the table shows typical differences in ion concentrations found in produced water and river water. Clearly, ground water and water in the near surface are often dilute and chemically different from formation water associated with gas oil. It can be shown from table 2 that the produced water accompanying the oil fields in southern Iraq dominated by sodium and calcium as positive ions and chloride and sulfate as negative ions. The presence of barium, calcium and sulfates ions in produced water result in an oilfield scale which cause corrosion and plugging problems.

We have adopted the style of governance the produced water through injection of water in the Dammam formation through disposal wells nearby isolation stations after a simple treatment and therefore the result is stopping wells from receiving any new quantities. Currently disposed of water can be done directly to the surrounding environment causing many operational and environmental problems.

The options that can be put to get rid of the water in economical and technical way might include the following:

1-discharging of associated water to any nearby water stream.

2-inject water in the produced formations (in the same field or nearby fields) or in the formations that are non-productive.

3-use evaporation pits on the way that the design and implementation of these pits are not allowed as regular attendant adsorption of water into the ground and mixing with groundwater.

In the treatment option, there are many technologies for the treatment of produced water and now with the ever tightening discharge limits around the world, there appears to be a glut of new technologies appearing to achieve the mandate of zero discharge into the environment.

After reviewing the major advantages and disadvantages of many treatment processes [5,7,8,25,26,27],one could conclude that treatment using membrane filtration have many significant advantages with low operating cost and low environmental effect in comparing with other treatment methods.

Obviously in order to be used safely and economically, an appropriate treatment method must be chosen or designed based on the water quality that is needed.

Virtually, most of technological improvements have been significant in the area of membrane filtration. The use of vibrating membrane mechanism to avoid membrane fouling is an effective and economical treatment solution for oil drilling operations [23].

Finally it is found that the best strategy to manage the produced water in any field is determined by many factors including the field location, available techniques, environmental determinants and cost. The options currently available include:1) reducing the water inside the cavity of the well by using mechanical and chemical methods. The mechanical one includes cementing, horizontal drilling, bridge plugs and well abandonment. the chemical option include the use of certain chemicals such as polymer gels or pre-gel forms, to be injected into the well to reduce the production of water and allow the continued production of hydrocarbons from them,2)block water from reaching the surface by using dual completion or down hole oil water separators. The latter technique reduces the water for his abdication in the well bore and injected into other formations,3)recycle and reuse of produced water. Sometimes the produced water can be used without treatment when it is clean or that the use of the final input for the conditions of high quality. The reuse options include:1)water injection in order to increase oil recovery,2)other uses such as agricultural crops or livestock or industrial uses ,3)water disposal options. Although there are many options for recycling and reuse, but large amounts of produced water is disposed of discharging to surface water bodies(after simple treatment) or is injected subsurface for the purpose of subsidized production.

Table 2: Summary of lower and higher values and the rate of the results of chemical analysis of produced water accompanying the oil in the Mishrif formation of two fields (ten wells) at southern Iraq.

Ion Species	Produced Water (ppm)		
	Min	Max	Average
Sodium	50000	86000	72500
Potassium	650	4000	1950
Magnesium	1500	3900	2650
Barium	150	460	260
Strontium	350	1500	610
Sulfate	120	1300	710
Chloride	120000	170000	135000
Calcium	7600	15100	11200
Cadmium	22	35	26
Chromium	70	110	90
Copper	60	90	70
Lead	110	280	210
Nickel	90	190	110
Zinc	66	150	87
Bicarbonates	40	600	320
Total Dissolved Solids	210000	280000	245000

Conclusions :

The treatment of produced water due to the recent and current technologies may be summarized as follows.

1- The produced water treatment methods have been classified within this study according to the type of contaminants namely suspended and dissolved hydrocarbons, and suspended and dissolved solids.

2- Many of world wide treatment options are presented and discussed in this study for their applications in petroleum industry involving costs and environmental effects.

3- The results showed that in addition to salt, many produced waters also

contain high levels of some heavy metals. Sodium, potassium, magnesium, barium, strontium, chloride, calcium, and lead were found to have the highest concentrations.

4- The use of water injection and the attributes of non-thought out can lead to several problems among them blockage of porous channels, corrosion in the crust of rocks, deposition of solids and the emergence of bacteria, which combined to reduce production rates.

5- The treated water with a certain level of purity is very essential at most of drilling sites and at production operations such as secondary oil recovery.

6- It was found that most of new technologies have both of issues: environmental protection and economical benefit. Also, most of new technological improvements are associated with membrane filtration where the filter design is based on water quality specifications. Moreover, the new techniques are designed to achieve the mandate of zero discharge into the environment.

7-It may be feasible to treat waters that slightly exceed regulatory limits for re-use in arid or drought areas, rather than losing them to discharge in the surrounding lands.

Recommendations :

The present study offers generally the objectives to delineate the following recommendations:

1- Knowing the kind of bearing rocks of theses waters facilitate the use of this water for aquifer injection of the same rock type and to reduce the negative effects that may result from injection of water in the current approved.

2- Chemical analysis of the produced water from other drilling locations are required to cover the wide range difference in its chemical composition and to design and select the proper treatment method.

3- One source of water should be taken into consideration for different field activities to avoid any future problems that could be resulted in case of mixing more than one type of water.

4- The following recommendations are proposals which do not intersect with the solutions landed status:

a) Use of three-phase isolators to accommodate the increasing water cut.

b) Construction of evaporation pits to suit fundamentalist away with quantities of produced water and within a specific environmental issues.

5-The mentioned new treatment technologies are recommended to be practiced to minimize the disposal besides the economical and environmental benefits.

6-Through hydro geochemical studies of reservoir water we can benefit from the water reservoir for certain fields for the purpose of injection into the nearby fields and thus can be rationalized net water consumption required for these purposes and may reduce the costs allocated to these projects.

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أدارة المياه المنتجه من الحقول النفطيه:المعالجه وأعادة الاستخدام والتخلص

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الخلاصة:

ان الماء المنتج يصاحب انتاج النفط والغاز خصوصا في الحقول التي تنتج بالدفع المائي او بالحقن المائي.ان كمية هذه المياه من المتوقع ان تصبح مشكله اكثر تعقيدا مع زيادة القطع المائي الذي من المتوقع ان يصبح 3-8برميل ماء لكل برميل نفط منتج.

يحتوي الماء المنتج على العديد من المكونات اعتمادا على ماموجود تحت السطح في موقع معين.ان الماء المنتج يحتوي على مواد صلبه مذابه وهايدروكاربونات(مذابه وعالقه) واوكسجين ناضب.الملح هو اكثر ماده صلبه مذابه بتراكيز تتراوح من عدة اجزاء لكل الف الى مئات الاجزاء لكل الف.اضافة الى الملح فان العديد من المياه المنتجه تحوي ايضا مستويات عاليه من العناصر الثقيله كالزنك والباريوم والكروميوم والرصاص والنيكل واليورانيوم والفانديوم ومستويات قليله من العناصر المشعه المتواجده طبيعيا.

تلقي هذه الدراسه الضوء على المفاهيم الرئيسيه لمختلف التجارب العالميه المتعلقه بمعالجة الماء المنتج لاغراض اعادة الاستخدام المتعاقب او التخلص.تتباين طرق المعالجه هذه بكفائتها وكلفتها وتاثيراتها البيئيه.

تم اخذ نماذج من الماء المنتج من تكوين المشرف في عشرة ابار تعود لحقلين نفطيين جنوب العراق وتم تحليلها كيميائيا لمعرفة السمات الرئيسيه لهذه المياه من اجل وضع الخطط لافضل استراتيجيه مطلوبه للتعامل مع زيادة القطع المائي في هذه الحقول.