UDC 665: 502.7
DOI 10.52171/2076-0515_2024_16_02_67_74

Environmental Impacts of Chemical Composition Produced Water

N.I. Mammadova

Azerbaijan State of Oil and Industry University (Azadlig ave. 34, Baku, AZ1010, Azerbaijan)

For correspondence:
Mammadova Nazila / e-mail: naza_366@mail.ru

Abstract

This paper examines the effect of produced water from oil and gas production on the environment. Produced water, a complex mixture of different organic and inorganic compounds (mostly salts, minerals, and oils), is a major wastewater generated during oil and gas production. The many chemical components found in formation water, in high enough concentrations, can present a threat to marine life when discharged into sea environments or when discharged to soil ecosystems. Produced water is an inextricable part of the hydrocarbon recovery process and it the important to optimize the management volume of this water. This water must be adequately handled, to prevent and/or minimize environmental degradation. The hydrochemical composition and its impact on the environment is given in the article. Thus, a disposal method was proposed to manage the volume of formation water in production and to increase its efficiency in the re-injected process (on the Siyazan field example).

Keywords: degradation, produced water, environment, anions, cations, utilization.

Received *08.05.2023*
Revised *11.06.2024*
Accepted *21.06 .2024*

For citation:
N.I. Mammadova
[Environmental Impacts of Chemical Composition Produced Water]
Herald of the Azerbaijan Engineering Academy, 2024, vol. 16, № 2, pp. 67-74 *(in English)*

Lay sularının kimyəvi tərkibinin ətraf mühitə təsiri

N.İ. Məmmədova
Azərbaycan Dövlət Neft və Sənaye Universiteti (Azadlıq pr. 16/21, Bakı, AZ 1010, Azərbaycan)

Xülasə

Məqalədə neft və qaz hasilatı nəticəsində yaranan lay suyunun ətraf mühitə təsiri nəzərdən keçirilir. Müxtəlif üzvi və qeyri-üzvi birləşmələrdən (əsasən duzlar, minerallar və yağlar) ibarət mürəkkəb qarışığı olan lay suyu neft və qaz hasilatı zamanı əmələ gələn əsas çirkab sularıdır. Lay sularında kifayət qədər yüksək konsentrasiyalarda tapılan bir çox kimyəvi komponentlər dəniz mühitinə və ya torpaq ekosistemlərinə atıldıqda təhlükə yarada bilər. Yataqların işlənilməsində lay suyu prosesin ayrılmaz hissəsidir və bu suyun həcminin idarə olunmasının optimallaşdırılması vacibdir. Ətraf mühitin tarazlığının pozulmasının qarşısını almaq və ya minimuma endirmək üçün lay suları utilizasiya edilməlidir. Belə ki, hasilatda lay suyunun həcmini idarə etmək və təkrar texnoloji proseslərdə onun səmərəliliyini artırmaq üçün utilizasiya üsulu təklif edilmişdir (Siyəzən yatağı timsalında).

Açar sözlər: deqradasiya, lay suyu, ətraf mühit, anion, kation, utilizasiya.

Воздействие химического состава пластовой воды на окружающую среду

Н.И. Маммадова
Азербайджанский государственный университет нефти и промышленности (пр. Азадлыг, 16/21, Баку, AZ1010, Азербайджан)

Аннотация

В статье рассматривается влияние пластовой воды при добыче нефти и газа на окружающую среду, которая представляет собой сложную смесь различных органических и неорганических соединений (в основном солей, минералов и масел), и является основным источником сточных вод, образующихся при добыче нефти и газа. Многие химические компоненты, содержащиеся в пластовой воде, в достаточно высоких концентрациях могут при сбросе в морскую среду или в почву представлять угрозу для морской жизни и экосистемы Земли. Пластовая вода является неотъемлемой частью процесса добычи углеводородов, который необходимо контролировать. С этой водой необходимо обращаться надлежащим образом, для предотвращения или сведения к минимуму отрицательного воздействия её на окружающую среду. В данной статье приведен гидрохимический состав пластовых вод и его влияние на окружающую среду. В работе также, был предложен способ утилизации, позволяющий управлять объёмом пластовой воды при добыче и повышать её эффективность в процессе обратной закачки в скважину на примере Сиязанского месторождения.

Ключевые слова: деградация, пластовая вода, окружающая среда, анионы, катионы, утилизация.

Introduction

Produced water (PW) is often generated during oil and gas production from onshore and offshore fields. Formation water (FW) is seawater or fresh water that has been trapped for millions of years with oil and gas in a geologic reservoir consisting of a porous sedimentary rock formation between layers of impermeable rock within the earth's crust.

Brine/produced water, and production chemicals sometimes are re-injected into a deep reservoir to enhance both recovery rates. The ratio of PW to oil and gas equivalents is widely from essentially zero to more than 50 (98% water and 2% oil). The volume of PW generated usually increases as oil and gas production decreases with the age of the well. In nearly depleted fields, production maybe 98% PW and 2% fossil fuel. Due to the aging of wells, it is also expected that the water-to-oil ratio will increase for crude oil resources by 2025 [1]. Thus, the market growth for the management and reuse of FW is expected to grow forth. There is an entailment for an effective management strategy that handles large amounts of FW and meets environmental regulations.

The typical oil field production showed in figure 1.

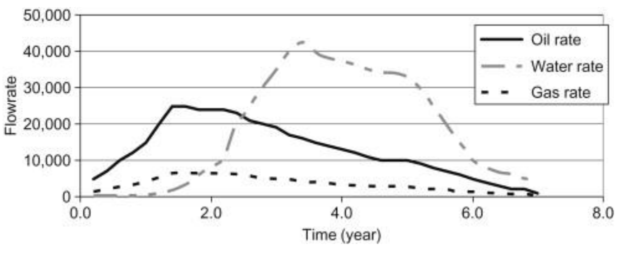

Figure 1 – Production prosses for a typical oilfield

FW is a mixture of dissolved and particulate organic and inorganic chemicals. The physical and chemical properties vary widely depending on the geological age, depth, and geochemistry of the hydrocarbon formation, as well as the chemical composition of the oil and gas phases in the reservoir, and production chemicals added to the production processes. Because no 2 produced drinks of water are alike, region-specific studies are needed to address the environmental negative risks from its discharge.

Some of the typical PW components are salts (expressed as salinity), oil and grease, benzene, toluene, ethylbenzene, xylenes (BTEX), polycyclic aromatic hydrocarbons (PAHs), organic acids, and phenols. And, chemical additives can be found that come from the drilling, fracturing, or the exploitation of the wells. In addition, some of them may have toxic properties [2]. These include biocides, demulsifiers, and scale and corrosion inhibitors from oil fields and methanol and diethylene glycol from gas fields [3-5].

The discharged PW to the environment is accompanied by a negative impact on natural complexes. The techno-physical impact is carried out on all areas environment – hydrosphere, atmosphere, and lithosphere. The qualitative properties of natural components deteriorate. As a result of the accident, the sources of environmental pollution by PW are generally – wells, pumping and compressor stations, storage depots, and pipelines [6].

PW discharges from offshore oil and gas platforms are a significant source of PAHs released to the aquatic. PAHs content in operational discharges from the offshore industry is a constant worry as many of the PAHs are toxic and lipophilic so they can be adsorbed by water organisms and concentrated along the food chain.

Alkylphenols and aromatic hydrocarbons from PW accumulate in benthic communities. This toxic component may disturb the reproductive functions of marine microfaunas. And may seriously affect genetic biomarkers in filter-feeding bivalves, sediment oxygen consumption, and mortality in benthic fauna [7]. Monitoring surveys find detectable exposures in caged mussels and fish several km downstream from PW outfalls, but biomarkers indicate only mild acute effects in these sentinels. On the other hand, increased DNA adduct concentrations are repeatedly found in benthic fish populations.

The toxic components in PW, which are adsorbed by the soil and enter groundwater and dramatically change their physic-chemical properties – salt composition, alkalinity, the reaction of soil suspensions, soil-absorbing complex, change the water-air regime, and carbon-nitrogen balance [8-10].

PW changes the state of ecosystems, leads to the degradation of biocenoses, and therefore the rate of transformation of the soil complex becomes much higher than in oil spills, and self-purification gets slow [10]. PW has a high salt concentration due to this the ions of the salts negatively affect the site's soil and vegetation, impairing its ability to produce crops and forage.

Due to the high concentration of soluble salts (predominately sodium chloride, NaCl), salinity negatively impacts soils in many ways. Chloride levels in and around the spill area are toxic to many biological species. Sodium is a natural dispersant and can cause soils to swell and disperse. However, the total salt level in the soil is below the flocculation threshold limit. Salinization of the soil absorbing complex with exchange sodium is the main cause of plant death with such pollution. Swelling soils will retain their natural structure, but soil structure will be lost once dispersion occurs. This structure loss impedes water's ability to infiltrate and move through the soil, increasing the potential for erosion. Salts in PW impair plants' ability to take up water and nutrients. High salt concentrations in the soil restrict the plants' ability to take up water despite adequate water being available in the soil, causing the plant to exhibit symptoms of drought [11]. Most plants will show signs of salt stress if sodium exceeds 70 milligrams per liter in water, 5 percent in plant tissue, or 230 milligrams per liter in soil (saturated paste extract) [11]. Chloride negatively impacts most plants when its concentration exceeds 350 milligrams per liter in water, 1 percent in plant tissue, or 250 milligrams per liter in soil [11].

Therefore, to neutralize the water's impact on the environment it is important to treat them for reuse. After treatment PW can be reused in these processes:

- discharged into the sea or evaporation ponds. This is subject to local environmental regulations.
- injected into a utilization well to liquidation.
- re-injected into the reservoir to increase pressure.

Materials and Methods

The Siyazan structure belongs to the Guba-Caspian oil and gas region 80 km northwest of Baku.

According to tectonic and geological-morphological indicators, there are the following oil and gas fields: Chandahar-Zarat, Siyazan-Nardaran, Saadian, Amirkhanli, and Zagli-Zeyva.

Approximately 800 tones of PW and 130 tones of oil are produced along with oil per day in the Siyazan oil fields. According to hydrochemical and physical analyzes shown in Table 1 and Table 2.

Table 1 – Physical parameters of produced water from Siyazan oil fields

Field	Mineral., g/l	pH	Density, g/cm^3	According to Palmer's classification				According to the Sulin classification	Flooding, %
				S_1	S_2	A_1	A_2		
Saadan	50,33	,1	1,0332	89,83	8,82	0	1,35	$CaCl_2$	88,5
Chandahar-Zarat	33,12		1,0220	86,70	5,92	0	7,38	$MgCl_2$	96,5
Siyazan-Nardaran	23,14		1,0150	90,58	5,44	0	3,98	$MgCl_2$	94,7
Amirkhanli	24,97		1,0170	87,42	8,92	0	3,66	$MgCl_2$	89,9
Zagli-Zeyva	34,21		1,0270	88,06	9,94	0	2	$CaCl_2$	91,8

Table 2 – Hydrochemical composition of water samples from Siyazan oil fields

Oil field	The number of elements in mg. l	Anions			Cations		
		Cl^-	HCO_3^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^++K^+
Saadan	mg/l	29805,75	198,15	-	743,90	602,36	17607,42
Chandahar-Zarat	mg/l	1,8387	0,2520	-	0,0364	5,63	1,1162
Siyazan-Nardaran	mg/l	1,3437	0,0960	-	0,0190	0,0337	0,8220
Amirkhanli	mg/l	1,4639	0,0960	-	0,0254	0,0501	0,8616
Zagli-Zeyva	mg/l	2,0509	0,0720	-	0,0444	0,0588	1,1951

According to the physical parameters obtained from the analyzes performed, the salinity of FW ranges from 50,33 g/l to 23,14 g/l.

Currently, there is quite a lot of classification of natural waters by chemical composition, but few have become widespread. The most commonly used in oil and gas hydrogeology are the classifications of R. Palmer and V.A. Sulin. Based on this, we have characterized the water samples of these deposits according to these classifications.

According to Palmer, classes are distinguished by the ratio of the sums of metal and acid ions. R. Palmer identifies salt characteristics. The first salinity is due to salts of bases and strong acids. The second salinity is determined by salts of alkaline earth metals and strong acids. The first alkalinity is due to alkali metal salts and salts of weak acids. The second alkalinity is the presence of salts of alkaline earth metals and weak acids.

According to Palmer, the studied water samples have the following salt characteristics:

• water sample from the Saadan oil field – first salinity (S_1)=89,83; second salinity (S_2)=8,82; second alkalinity (A_2)=1,35; first alkalinity (A_1)=0;

• water sample of the Chandahar-Zarat oil field: (S_1)=86,70, (S_2)=5,92, (A_1)=0, (A_2)=7,38;

• water sample of the Siyazan-Nardaran oil field: (S_1)=90,58, (S_2)=5,44, (A_1)=0, (A_2)=3,98;

• water sample of the Amirkhanli oil field: (S_1)=87,42, (S_2)=8,92, (A_1)=0, (A_2)=3,66;

• water sample of the Zagli-Zeyva oil field: (S_1)=88,06, (S_2)=9,94, (A_1)=0, (A_2)=2;

Based on the analysis, it follows that according to Palmer, these water samples are classified as class 3 - water with constant hardness (that is, water is characterized by S_1, S_2, A_2, A_1=0).

According to the classification of waters and V.A. Sulin, these water samples are attributed as the calcium chloride ($CaCl_2$) and magnesium chloride ($MgCl_2$) types.

Based on this table we can see the percent flooding of oil wells. Mainly, PW on the Siyazan oil field was re-injected into the utilization wells [12]. And it plays a crucial role in the volume management of PW.

The analysis of 379 formation water samples from 37 production and exploration wells was carried out.

Based on these tables, we can see that the dominance of Na^{+}+K^{+} ions is observed among cations. The highest content of these ions was noted in the water sample of the Saadan oilfield. And among the anions, Cl^{-} ions predominate, and the highest content was noted in the water sample of the Saadan oilfield. Sulfate and sulfide concentrations in the produced water usually are low. When these ions present in PW allowing barium and other elements that form insoluble sulfates and sulfides are present in the solution at high concentrations.

The purpose of the work

The rational use of PW from the Siyazan oil fields is in the final stage of development. Also, to reduce the negative impact of this water on the environment, management of volume and increase the efficiency of reusing to the technological processes. Hardness FW on Siyazan fields should be treated to reduce the aggressive effect on oil and gas equipment. This will serve the longevity of the equipment. For this purpose, the changed of the physical and chemical parameters of PW by the addition of 1,0% Al (50-70 nm) nanoparticles (NPs) into alkalized diesel fractional waste (ADFW). So, the water hardness has decreased due to the composite. This increases the efficiency of water reuse. Thus, it is opportune to use PW to increase reservoir pressure in the final stage of operation. Because, after the addition of the composite, the water content has adapted to the required condition.

Most PW have salinities greater than that of seawater and, therefore, are denser than seawater. PW of Siyazan oil fields is salinity classified as class 3 – water with constant hardness. PW contains the same salts as seawater, with sodium and chloride being the most abundant ions. The most abundant inorganic ions in high-salinity PW are, in order of relative abundance in PW, sodium, chloride, calcium, magnesium, potassium, sulfate, bromide, bicarbonate, and iodide. The concentration ratios of many of these ions are different in seawater and PW, possibly contributing to aquatic toxicity.

According to the results of the analyzes, we determined the type of FW by the Palmer method, and FW produced in the field is of MgCl type. The FW sample was mixed with the addition of 1,0% Al (50-70 nm) nanoparticles (NPs) to alkalized diesel fractional waste (ADFW) and the change in water composition was observed. The results of the analyzes are given in Table 3, respectively.

Table 3 – Effect of 1,0 % (Al) NPs mixture of ADFW on chemical and physical parameters of PW (in 100 ml of PW)

Additive volume ml	**Cations**			**Anions**			**pH**	**According to Palmer classification**				**Miner g/l**	**Hardness, mg.eq/l**
	Na^{+}+K^{+}	**Ca^{2+}**	**Mg^{2+}**	**Cl^{-}**	**CO_3^{-}**	**HCO_3^{-}**		**A_1**	**A_2**	**S_1**	**S_2**		
0	46,25	0,90	2,85	47,64	0,21	2,15	7	0	4,3	92,5	2,78	28,58	3,64
2,5	46,98	0,34	2,68	47,49	0,34	2,17	7	0	4,34	93,96	1,02	27,84	2,85
5	48,02	0,26	1,72	46,92	0,52	2,56	8	2,2	3,96	93,84	0	27,36	1,83
7,5	48,41	0,27	1,32	46,58	0,71	2,71	8	3,66	3,18	93,16	0	26,74	1,43

As can be seen from Table 3, CO_3^- and HCO_3^- ions increased with the addition of the composite to the PW, and Na^++ K^+ ions increased too. Ca^{2+} decreased significantly by 0,90 mg/l to 0,27 mg/l, and Mg^{2+} ions decreased by 2,85 mg/l to 1,32 mg/l respectively. And Cl^- ion content decreased by 47,64 mg/l to 46,58 mg/l. A comparison of water samples analyzes (Tab. 3) shows there is a positive change in the characteristics of the water and its hardness decreased significantly (1,43 mg.eq/l), and the mineral content of the sample decreased (26,74 g/l) from hard water to soft water. Its type changed and became alkaline. Thus, this fully meets the requirements for the preparation of water by condensation. Due to the above reasons, there has been a change in the type and nature of FW, a further increase in aggressive properties, and the volume of formation water. As a result, the natural landscape of the surrounding areas has been disturbed, the soils became saline and unusable, and underground and surface equipment has been corroded. Nowadays, corrosion is one of the outstanding challenging problems in the industry. Modern industrial designs can never be made without taking into consideration the effect of corrosion on the life span of the equipment.

Thus, the utilization of PW is one of the important issues to prevent the listed negative effects. Produced water contains abundant corrosive substrates, which will result in a significant threat to safe operation and also leads to huge economic losses . The studies of the effects of the PW on the corrosion of the pipelines and the equipment in the petroleum industry have become more important. The equipment corrosion mainly resulted from the dissolved oxygen, Cl^- and another inorganic salt in PW.

From Table 3 it is seen that the effect of the composite prepared in ADFW on the hard water sample was high. Thus, the composite can also be effective against corrosion of the equipment.

Conclusion

The results of laboratory scientific research show that the 1,0% Al NPs in ADFW hardness reduces significantly (1,43 mg.eq/l), and the mineral content of the sample decreased (26,74 g/l) too. It also reduces the amount of Cl- ions that directly cause corrosion of oil field equipment.

Conflict of Interests

The author declare there is no conflict of interests related to the publication of this article.

REFERENCES

1. **Jerry M.N., Kenneth L, Elisabeth M.D,** 2011, Produced water; Overview of Composition, Fates, and Effects, researchgate, July. *(in English)*
2. **Jimenez S., Mico M.M., Arnaldos M., Medina F. and Contreras S.** (2018) State of the Art of Produced Water Treatment. Chemosphere, 192, 186-208. *(in English)*
3. **Igunnu E.T. and Chen G.Z.** (2014) Produced Water Treatment Technologies. International Journal of Low-Carbon Technologies, 9, 157-177. https://doi.org/10.1093/ijlct/cts049*(in English)*
4. **Danforth C., Chiu W.A., Rusyn I., Schultz K., Bolden A., Kwiatkowski C. and Craft E.** (2020) An Integrative Method for Identification and Prioritization of Constituents of Concern in Produced Water from Onshore Oil and Gas Extraction. Environmental International, 134, Article ID: 105280.
5. **Henderson S.B., Grigson S.J.W., Johnson P. and Roddie B.D.** (1999) Potential Impact of Production Chemicals on the Toxicity of Produced Water Discharges from North Sea Oil Platforms. Marine Pollution Bulletin, 38, 1141-1151. https://doi.org/10.1016/S0025-326X(99)00144-7*(in English)*
6. **Askarova M.A., Mussagaliyeva A.N.** (2014), The ecological situation in contaminated areas of oil and gas exploration in Atyrau region, Procedia-Social and Behavioral Sciences 120, p. 455-459.
7. **Beyer J., Goksoyr A., Hjerman D.O., Klungsoyr J., 2020,** Environmental effects of offshore produced water discharges: A review focused on the Norwegian continental shelf, Marine Environmental Research, Volume 162. *(in English)*
8. **Artemeva T.I.,** (1989), Systems of soil animals and issues remediation technological areas, Moscow, Science, pp.72–75. *(in English)*
9. **Ekaterina I. Kovaleva, Sergey Ya. Trofimov, Cheng Zhongqi** (2020), Impact of oil contamination on ecological functions of peat soils from West Siberia of Russia, Journal of Environmental Quality, Volume 50, p.49-62. *(in English)*
10. **Mengxue Hu,** (2020), Environmental Behavior of Petroleum in Soil and its Harmfulness Analysis, II 2nd International Conference on Air Pollution and Environmental Engineering, Volume 450, IOP Conference Series: Earth and Environmental Science. *(in English)*
11. **Meehan M., Sedivec K., DeSutter T., Augustin C., Daigh A.,** 2017, Environmental Impacts of Brine (Produced Water), NDSU, Publications, Environment & Natural Resources, R1850 June. *(in English)*
12. **Mürvətov F.T., Usubəliyev B.T., Rzayeva A.Q., Həsənova M.M., Kərimova A.Q.** Kompozitlərin hazırlanmasında neft sənayesinin maye tullantılarının istifadəsinin mümkünlüyü, *Azərbaycan Mühəndislik Akademiyasının Xəbərləri*. Cild 13. № 1, 2021. S. 74-79 *(in Azerbaijani)*