RESEARCH ARTICLE

Geochemical Characteristics and Significance of shale Gas Well Flowback Fluid in Zheng'An Block, Guizhou

Fengying Yang[1], **Zhongyun Chen**[2,*] **and Xiaojun Zhu**[1]

[1] Guizhou Shale Gas Exploration and Development Co., Ltd., Zunyi 563499, China
[2] Guizhou Wujiang Shale Gas Exploration Co., Ltd., Zunyi 563400, China

Abstract

Analysis of fracturing flowback fluids from 14 shale gas wells across 7 platforms in the Zheng'an block, Guizhou, reveals that the fluids are characterized by high salinity, elevated Na^+ and Cl^- concentrations, and high levels of chemical oxygen demand (COD) and ammonia nitrogen. Na^+ concentrations range from 7370 to 27396 mg/L (mean 18689 mg/L), Cl^- from 9000 to 43000 mg/L (mean 29438 mg/L), and total salinity from 17074 to 70950 mg/L (mean 48744 mg/L). The dominant microbial populations comprise iron bacteria (FEB), saprophytic bacteria (TGB), and sulfate-reducing bacteria (SRB). These characteristics indicate that the flowback fluid cannot be discharged directly without treatment. However, following appropriate pretreatment—including advanced oxidation for COD reduction, chemical flocculation for suspended solids removal, and biocide addition for microbial control—the fluid can be either recycled for further shale gas development or discharged after meeting the required standards, such as those specified in the Guizhou Province Pollution Discharge Standard (DB 52/864-2022). Sulfate-reducing bacteria and other microorganisms contribute to scaling, corrosion, and perforation of downhole tubing, surface equipment, and gas transmission pipelines; such damage can be effectively mitigated by regular biocide application during shale gas production. These findings provide critical data support for the treatment and recycling of shale gas flowback fluids in Guizhou, contributing to improved shale gas reserve development and production efficiency in the region.

Keywords: shale gas, flowback fluid, water quality, geochemical characteristics, gas well impact, Guizhou Zheng'an.

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***Corresponding author:**
Zhongyun Chen
2834627227@qq.com

1 Introduction

The shale in the Zheng'an block of Guizhou is tight and low-permeability in nature. Therefore, multi-stage fracturing before mining is the core technology for increasing production in shale gas development [1, 2], and the chemical constituents of the resulting fracturing waters require systematic analytical characterization [3]. Through fracturing, a network of cracks is created to achieve the necessary reservoir permeability for production; the resulting flowback water requires proper management, including

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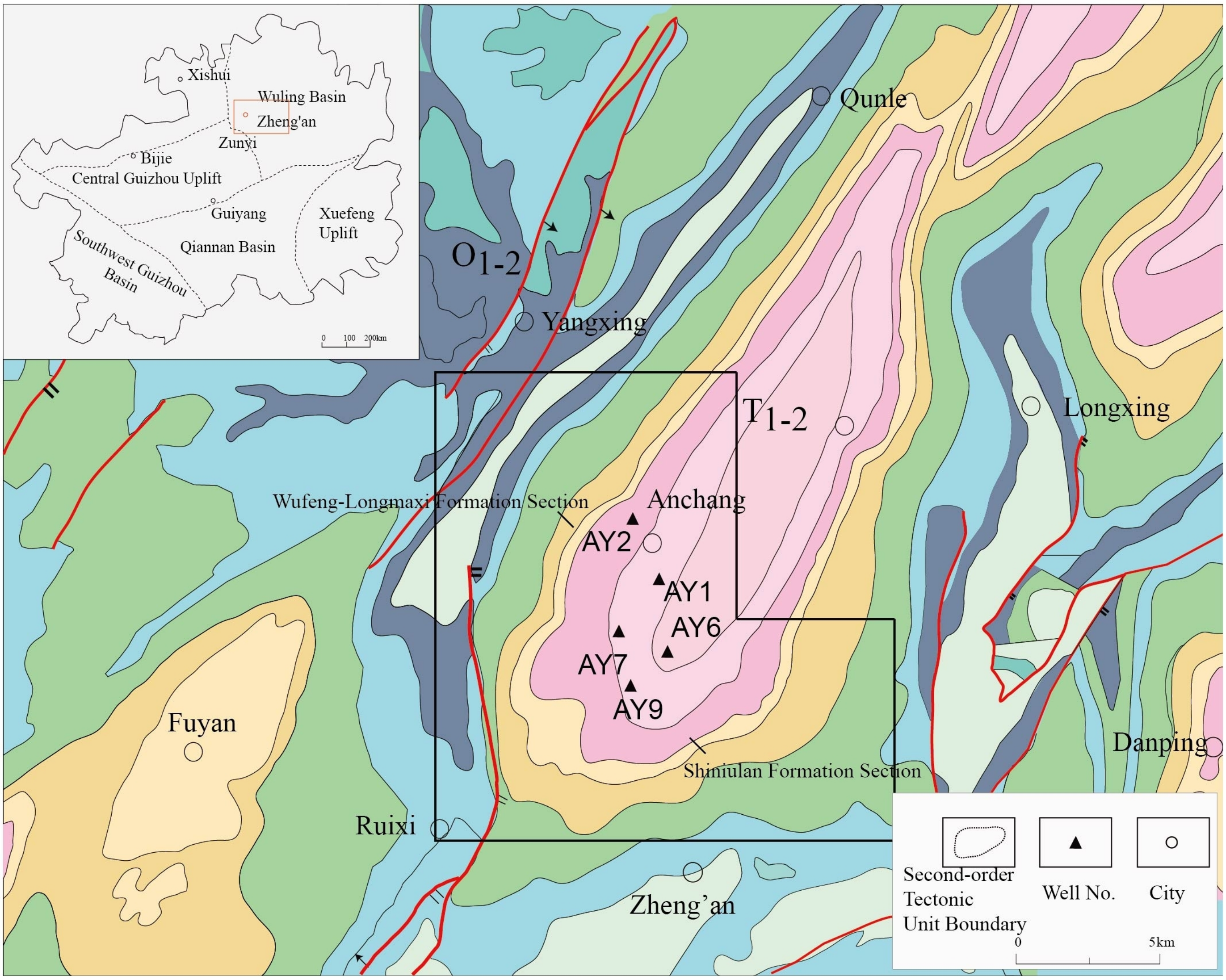

Figure 1. Location map of the study area.

recycling for subsequent fracturing operations to reduce the water footprint and maintain water quality [4]. In the Sichuan Weiyuan shale gas field [5], flowback fluid salinity, sodium, chlorine, boron, barium, manganese, and other parameters have been reported to far exceed emission standards; in the Chongqing Fuling area [6], six heavy metals (Li, V, Cu, Ga, Rb, and Ba) together with Na^+ and Cl^- have been shown to significantly contribute to the comprehensive toxicity of fracturing flowback fluid, necessitating treatment prior to discharge. Therefore, if the flowback fluid is not properly treated prior to reinjection or discharge, it may cause scaling and corrosion to downhole strings; moreover, direct discharge of untreated fluid poses significant risks to surface water and groundwater resources [7].

The economical, effective and green development of shale gas is a problem that has attracted much attention at present. In the process of shale gas exploitation, the flowback fluid will be brought to the surface and collected in storage pools. Some of the flowback fluid will be recycled after pretreatment, and some will enter the sewage treatment plant for treatment; isotopic and geochemical indicators can be used to trace the origin and evolution of such flowback and produced waters [8]. The composition of fracturing flowback fluid can accurately reflect the interaction between fracturing fluid and formation, and reflect the effect of fracturing on production [9, 10]. Previous studies mainly focused on shale gas in the Sichuan Basin. The study of shale gas fracturing flowback fluid mainly includes ion composition characteristics, total salinity and stable isotope ratio, and clarifies the influence of fracturing fluid characteristics on exploration and development [11]. However, shale gas in Guizhou started late. The Zheng'an block started the development of the test well group in

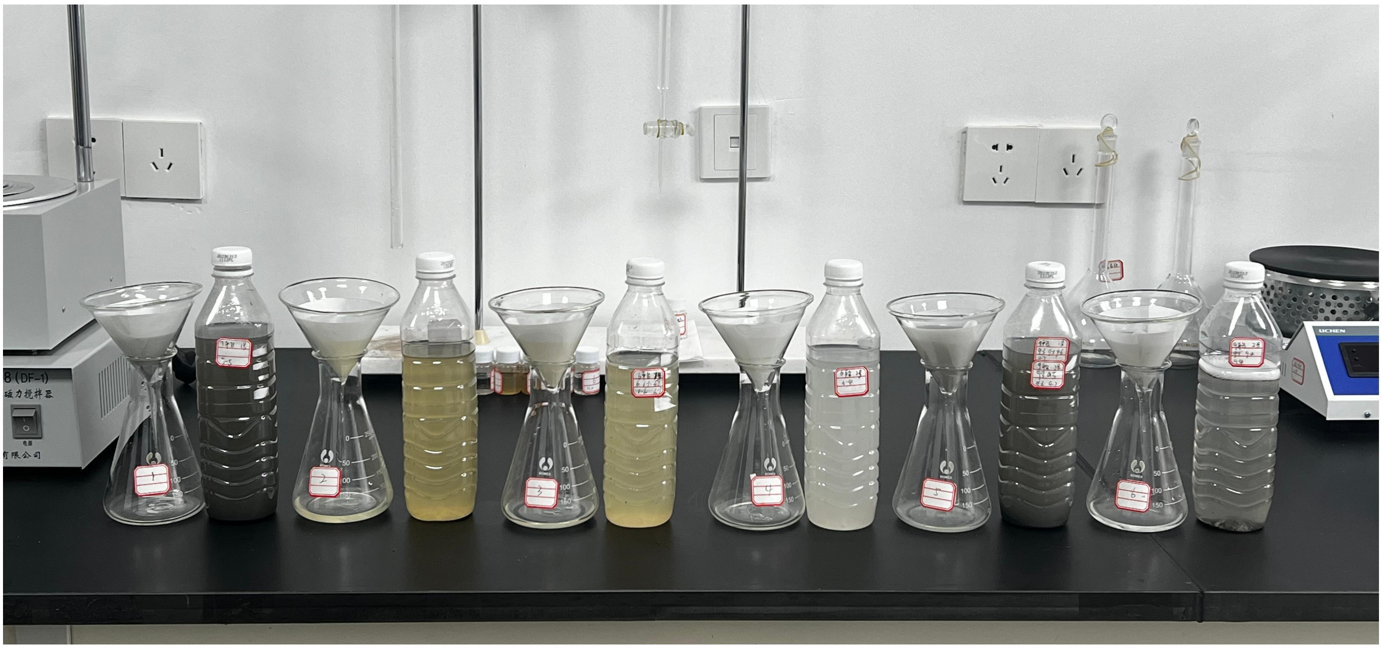

Figure 2. Flowback fluid samples of different gas wells.

2019, and has now entered the stage of large-scale start-up. The Zheng'an shale gas field, the first confirmed shale gas field in Guizhou Province, was officially established. In 2025, the output exceeded 300 million cubic meters, and the cumulative output exceeded 1 billion cubic meters. Most scholars mainly studied the preservation conditions of shale gas in Guizhou, drilling technology, fracturing, drainage and gas recovery technology, etc., and some scholars only studied the geochemical characteristics of shale gas flowback fluid in AY7-4 well of the Zheng'an block [12], which has limitations. There are differences in the properties of flowback fluids between gas wells. Therefore, this paper analyzes the anions and cations, salinity, COD and microorganisms of the flowback fluids of 14 gas wells on 7 platforms of the Zheng'an Block, deeply studies the composition of the flowback fluids, clarifies the characteristics of different gas wells in the block, and puts forward suggestions for the reuse of the flowback fluids, in order to provide data support for the treatment of shale gas flowback fluids and the recycling of gas well fracturing fluids, which is of great significance for improving shale gas reserves and production efficiency in Guizhou.

2 Geological Background of the Study Area

The Zheng'an block in Guizhou is structurally located in the Anchang syncline in the Wuling fold area (Figure 1), which is located in the structural transition zone between the southeastern margin of the Middle and Upper Yangtze Platform and the edge of the Sichuan Basin [13]. It is adjacent to the Sichuan Basin in the west, the Jiangnan tectonic belt in the east, and the Xuefeng Mountains in the southeast. The Wufeng–Longmaxi Formation constitutes the primary shale gas reservoir horizon in this block, and lithofacies identification indicates favorable gas-bearing potential in the northern Guizhou region [14]. In the long geological history, the Wuling Mountain area has experienced many tectonic movements, which is consistent with the tectonic evolution of the middle and Upper Yangtze platform. It is mainly superimposed by multi-stage tectonic movements such as the formation period of the Mesoproterozoic-Late Proterozoic crystalline basement, the Caledonian period, the Hercynian-Indosinian period, and the Yanshanian-Himalayan period, and finally the geological process of fold orogeny, forming a complex tectonic framework of the current Yangtze platform [13].

The study area is geographically located in Anchang Town, Zheng'an County, Zunyi City, Guizhou Province. It is adjacent to Wuchuan Autonomous County in the east, Tongzi County in the west, Fenggang, Suiyang and Meitan counties in the south, and Daozhen Autonomous County in the north. It is adjacent to Fuling, Nanchuan, Wulong, Pengshui and Qianjiang shale gas exploration and development zones in Chongqing [13], with a total area of 695 km^2. Shale gas sweet spot prediction and optimal well deployment in this block have been investigated to support efficient development of the

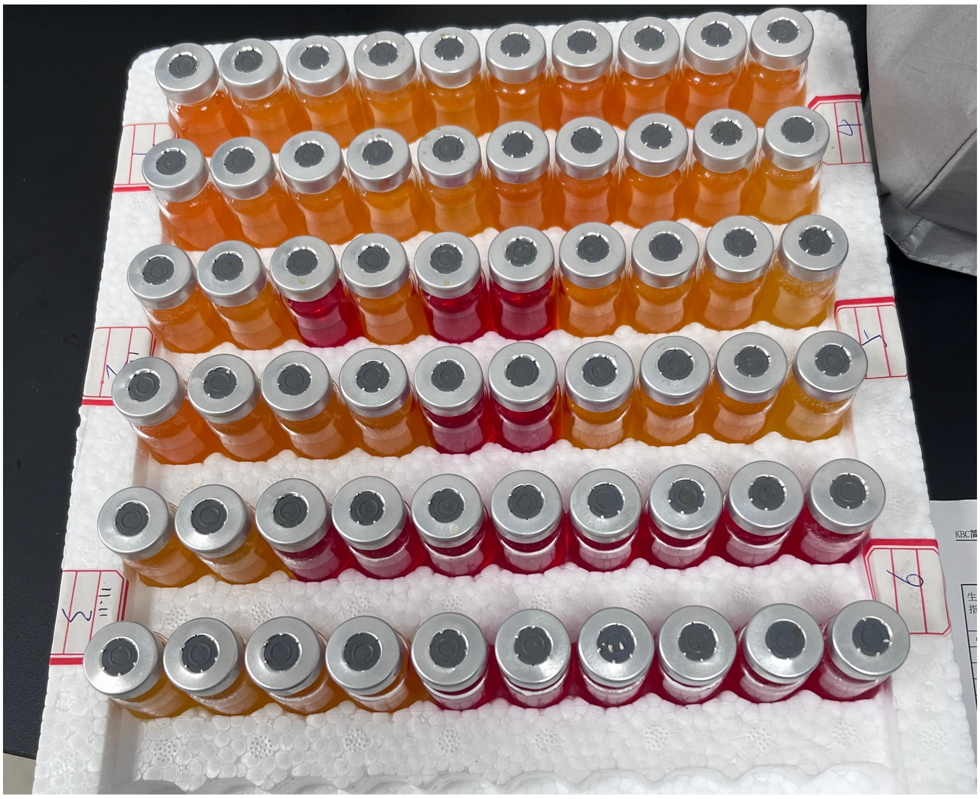

Figure 3. Simplified bacterial testing method.

Wufeng–Longmaxi Formation [15].

The faults and folds in the study area are well developed; the structural combination is complex, and the strata are mainly normal pressure. The main research horizon is the Wufeng-Longmaxi Formation, with a thickness of 1500–4500 m and a lateral extent of approximately 1000–2000 m. The sedimentary facies are deep-water shelf and shallow-water shelf. The lower part of the Wufeng-Longmaxi Formation is mainly gray carbonaceous shale and black shale, rich in graptolite fossils. The upper part is calcareous and sandy, mainly sandy shale and marl, and the fossils are reduced. The Wufeng Formation is dominated by black shale and argillaceous limestone. On the whole, the TOC at the bottom of the Longmaxi Formation is the highest. It can be seen that there is a bioelastic limestone in the Guanyinqiao section between the two, which is a regional marker layer with a thin thickness.

3 Sampling and Analytical Methods

Fourteen samples of fracturing flowback fluid were collected from 14 gas wells in the Zheng'an block. The sampling interval between two wells on the same platform was 5 days, with flowback times varying between wells. The samples were collected using a gas-liquid separator (Figure 2). The collected water samples were stored in plastic bottles that had been pre-rinsed with deionized water and subsequently rinsed three times with the collected water sample to minimize contamination before final collection. Water samples were slowly introduced into the bottles to expel residual air, thereby minimizing oxidation and reducing measurement error. All samples were sent to the laboratory on time after sampling, and analysis was completed within 2 hours of collection to minimize sample alteration. All samples were filtered through 0.45 μm membrane filters to remove suspended solids prior to analysis.

Major cations and anions, total iron, ferrous iron, dissolved oxygen, sulfur, COD, and ammonia nitrogen were measured using a multi-parameter water quality field tester (Model ZZW-II) with rapid test tubes. The instrument complies with national environmental protection standards (Technical Specification for Emergency Monitoring of Environmental Incidents, HJ 589–2010) and Sinopec enterprise standards. The test principle involves breaking the test tube in the water sample, allowing quantitative absorption of the sample, color development, and measurement via colorimetry.

Sulfate-reducing bacteria (SRB), saprophytic bacteria (TGB), and iron bacteria (FEB) were tested using the KBC series of bacterial simple test bottles (Figure 3). This series of products adopts the principle of the MPN

Table 1. Example of bacterial growth indicator readings.

Example	Growth Observation					Growth Indicator	Series	Bacterial Count (cells/mL)
	1# Bottle	2# Bottle	3# Bottle	4# Bottle	5# Bottle			
	Series 0	Series 1	Series 2	Series 3	Series 4			
1	+-	- -	- -	- -	- -	100	10^0	0.6×10^0
2	++	++	- -	- -	- -	200	10^1	2.5×10^1
3	++	++	++	++	- -	220	10^2	25×10^2
4	++	++	++	++	++	222	10^2	$\geq110\times10^2$

method and high-pressure sealed storage, abandoning the constraints of aseptic conditions, so that microbial detection can also be realized in non-biochemical laboratories. SRB, TGB, and FEB were quantified using the serial dilution extinction method (standard SY/T 0532-2012). To improve quantification accuracy, each sample was analyzed in duplicate. The water sample to be tested was injected into the test bottle step by step with a 1 mL sterile syringe for inoculation and dilution. The test bottle after inoculation and dilution was cultured in a constant-temperature incubator at 33 °C (optimal growth temperature range: 30–33 °C). The culture time of saprophytic bacteria (TGB) was 1 day. The culture time of sulfate-reducing bacteria (SRB) and iron bacteria (FEB) was 7 days. After the culture, according to the positive reaction of the bacterial bottle and the multiple of dilution, the growth index, series and base number (see Tables 1, 2) were determined, and the number of bacteria in the water sample was calculated. The total bacterial count was calculated as the product of the bacterial base number and the dilution series factor. This method has the random error of the secondary repeated dilution operation, the scale deviation of each sampling of the syringe, and the random distribution of microorganisms in the water, resulting in a certain error in the results.

Table 2. Secondary duplicate bacterial base number table.

Indicator	Bacterial Base Number (cells/mL)
000	0
001	0.5
010	0.5
011	0.9
220	25.0
222	110.0
020	0.9
201	5.0
100	0.6
210	6.0
101	1.2
211	13.0
110	1.3
212	20
120	2.0
221	70.0
111	2.0
121	3.0
200	2.5

4 Results

4.1 Elemental Geochemistry

4.1.1 Major Cations and Anions

Analysis of flowback fluids from various platforms in the study area (Table 3) shows that the dominant cations are Na^+, Ca^{2+}, and Mg^{2+}. Na^+ ranges from 7370 to 27396 mg/L (average 18689 mg/L), Ca^{2+} from 299 to 480 mg/L (average 402.6 mg/L), and Mg^{2+} from 86 to 162 mg/L (average 143 mg/L).

The dominant anions are Cl^-, HCO_3^-, and CO_3^{2-}. Cl^- ranges from 9000 to 43000 mg/L (average 29438 mg/L), HCO_3^- from 130 to 365 mg/L (average 178 mg/L), and CO_3^{2-} from 40 to 370 mg/L (average 132 mg/L). No SO_4^{2-} was detected.

Overall, cations follow the order $Na^+ > Ca^{2+} > Mg^{2+}$, and anions follow $Cl^- > HCO_3^- > CO_3^{2-} > SO_4^{2-}$ (Figure 4). The high concentrations of Na^+ and Cl^- classify the fluid as high-salinity contaminated wastewater. Pretreatment before reinjection is necessary. Divalent cations such as Ca^{2+} and Mg^{2+} are prone to precipitation; without treatment, reinjection could cause fracture plugging [16]. A Schoeller diagram comparing the major ion concentrations in the Zheng'an block flowback fluids with those from the Weiyuan and Changning areas is presented in Figure 4.

4.1.2 Salinity

Salinity, a key water quality parameter, reflects the total dissolved salt content in water, expressed as the sum of all cationic and anionic concentrations. It is

Table 3. Geochemical composition of flowback fluid in the Zheng'an block and adjacent areas Weiyuan and Changning (Weiyuan, Changning data from [5, 17–20]; microbial community characteristics of Sichuan Basin shale gas wastewater from [21]).

Sample No.	Well No.	Cations (mg/L)			Anions (mg/L)					Salinity (mg/L)
		Na^+	Ca^{2+}	Mg^{2+}	Cl^-	SO_4^{2-}	HCO_3^-	CO_3^{2-}	OH^-	
1PT-1	AY1-7HF	9449	402	153	15421	0	190	160	0	25773
1PT-2	AY1-4HF	13066	300	154	20916	0	145	100	0	34680
2PT-1	AY2-6HF	24239	460	148	38002	0	290	370	0	62847
2PT-2	AY2-3HF	24222	480	160	38000	0	365	370	0	62862
3PT-1	AY3-2HF	27396	401	156	43000	0	210	220	0	70950
3PT-2	AY3-5HF	7370	299	86	12000	0	160	40	0	19756
4PT-1	AY4-5HF	19410	320	155	30800	0	145	40	0	50869
4PT-2	AY4-3HF	20234	302	142	32000	0	145	40	0	52861
6PT-1	AY6-2HF	22617	479	162	36000	0	160	68	0	59257
6PT-2	AY6-6HF	7389	453	156	9000	0	115	160	0	17074
7PT-1	AY7-5HF	25298	402	162	40000	0	145	70	0	65858
7PT-2	AY7-8HF	18144	420	152	29000	0	130	72	0	47718
9PT-1	AY9-3HF	20039	480	160	32000	0	145	100	0	52679
9PT-2	AY9-2HF	22634	439	160	36000	0	146	40	0	59234
Weiyuan		7334	297	32	12578	/	/	/	/	/
Changning		12574	686	89	21073	/	/	/	/	/

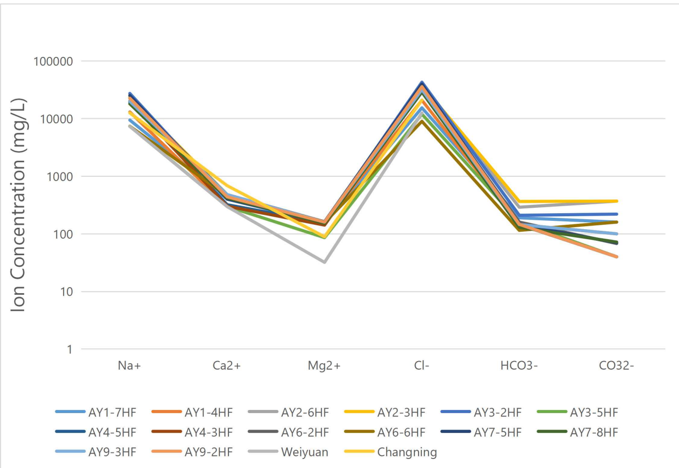

Figure 4. Schoeller diagram of main ions in flowback fluid of each well in Zheng'an block (Weiyuan and Changning data from [5, 17–20]).

an important reference index for testing water quality. In this experiment, the salinity of 14 samples was analyzed. The results are shown in Figure 5. The salinity of each platform in Zheng'an block was higher, and the average salinity of each platform was ranked from largest to smallest: 2PT > 7PT > 9PT > 4PT > 3PT > 6PT > 1PT. Among them, AY3-2HF was the highest, which was 70950 mg/L, and AY6-6HF was the lowest, which was 17074 mg/L. In the same gas mining platform, the geological conditions are basically the same, and the change of salinity has certain rules. As the flowback time becomes longer, the salinity also increases. The change of salinity is different in different gas mining platforms.

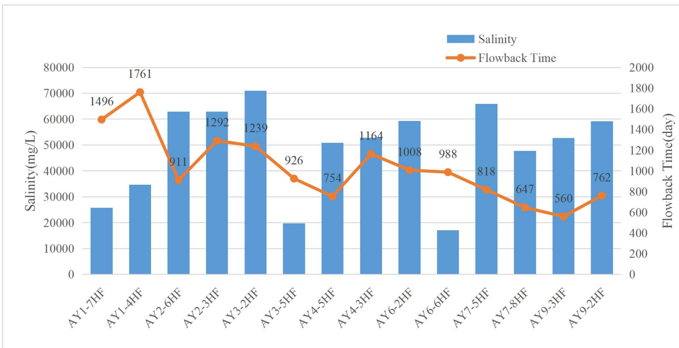

Figure 5. Relationship between salinity and flowback time of flowback fluid.

4.2 Other Parameters

4.2.1 Total Iron, Ferrous Iron, Dissolved Oxygen, COD, and Ammonia Nitrogen

As shown in Figure 6, the water in the Zheng'an block contains total iron, ferrous iron, dissolved oxygen, COD, suspended solids, ammonia nitrogen and other indicators. The total iron content ranged from 0.3

to 11.4 mg/L (average 1.94 mg/L), with the highest value recorded in well AY1-4HF. The ferrous iron content ranged from 0 to 9.05 mg/L (average 1.5 mg/L), the dissolved oxygen content ranged from 0.62 to 7.00 mg/L (average 2.99 mg/L), and the COD content ranged from 0 to 9801 mg/L (average 2740.57 mg/L). The content of ammonia nitrogen ranged from 50 to 146 mg/L (average 75.2 mg/L). The content of suspended solids ranged from 254.61 to 12942.86 mg/L, with an average of 3586.37 mg/L.

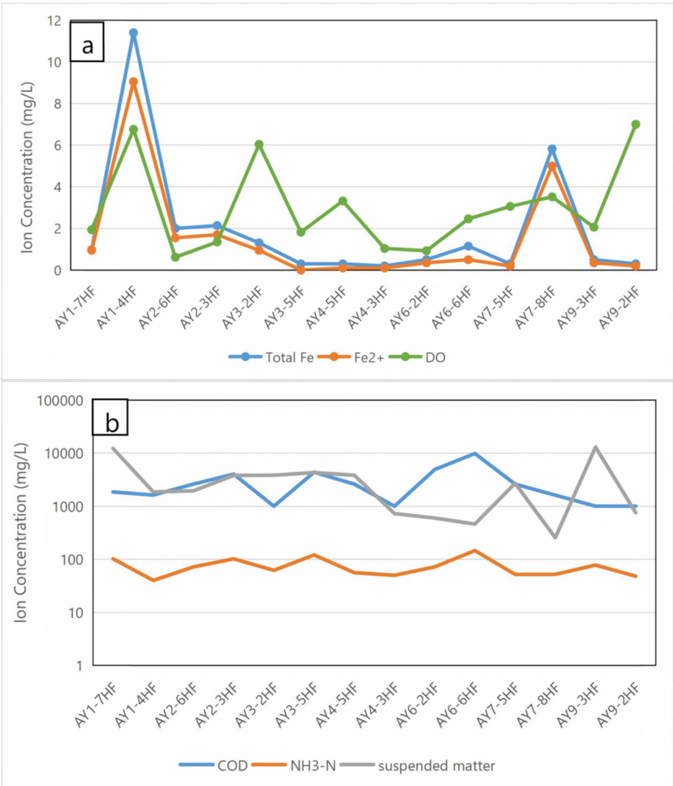

Figure 6. a. Total iron, ferrous iron, and dissolved oxygen content in flowback fluid of different gas wells; b. COD, ammonia nitrogen, and suspended solids content.

COD and ammonia nitrogen are the most prominent pollutants, following the concentration order COD > suspended solids > ammonia nitrogen > dissolved oxygen > total iron > ferrous iron. High COD indicates severe organic pollution. Dissolved oxygen, total iron, and ferrous iron significantly influence corrosion of downhole tubing and pipelines.

4.2.2 *Microbial Composition*

Test results show saprophytic bacteria (TGB) ranging from 0 to $\geq$ 11,000 cells/mL (average 3152 cells/mL), sulfate-reducing bacteria (SRB) from 0 to 1100 cells/mL (average 276 cells/mL), and iron bacteria (FEB) from 0 to 110 cells/mL (average 10.9 cells/mL). The distribution of these bacterial populations across different gas wells is illustrated in Figure 7.

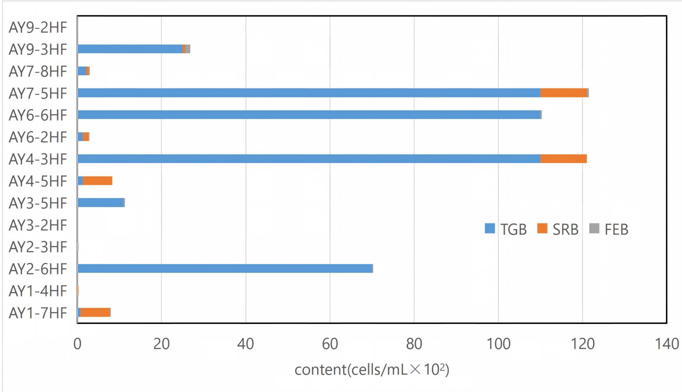

Figure 7. Bacterial content in flowback fluid of different gas wells.

5 Discussion

5.1 Characteristics and sources of flowback fluid

Analyzing and clarifying the geochemical characteristics of the flowback fluid is of great significance for its recycling, reducing environmental pollution, and optimizing the fracturing system and effect. Comparing the various ions of the flowback fluid in the Zheng'an block with the Changning and Weiyuan areas of the neighboring Sichuan Basin [5, 17–21], the Cl^- content of the flowback fluid in the Zheng'an block is 9000–43000 mg/L (average 29438 mg/L). The Cl^- content in the Changning area is 7691–31688 mg/L (average 21073 mg/L), and the Cl^- content in the Weiyuan area is 5370–37068 mg/L (average 12578 mg/L), which is lower than that of the Zheng'an block but overlaps in range with the Changning area. The Na^+ content in the flowback fluid of the Zheng'an block is 7370–27396 mg/L (average 18689 mg/L). The Na^+ content in Changning area is 4465–18690 mg/L (average 12574 mg/L). The Na^+ content in Weiyuan area is 3954–20864 mg/L (average 7334 mg/L), which is close to that in Changning area. The Ca^{2+} content of flowback fluid in Zheng'an block is 299–480 mg/L (average 402.6 mg/L). The Ca^{2+} content in Changning area is 168–1203 mg/L (average 686 mg/L). The Ca^{2+} content in Weiyuan area is 118–1823 mg/L (average 297 mg/L). The content of Mg^{2+} in the flowback fluid of Zheng'an block is 86–162 mg/L (average 143 mg/L), the content of Mg^{2+} in Changning area is 22–134 mg/L (average 89 mg/L), and the content of Mg^{2+} in Weiyuan area is 14–49 mg/L (average 32 mg/L); the contents of Ca^{2+} and Mg^{2+} are higher than those in Weiyuan area. The contents of Na, Ca and Mg in normal seawater are 11060 mg/L, 420 mg/L and 1330 mg/L, respectively [22]. The content of Na^+ in most wells of Zheng'an flowback fluid is higher than that of normal seawater, while the contents of Ca^{2+} and Mg^{2+} in most wells are lower than those of normal seawater, and the content of Mg^{2+} is much lower than that of normal seawater. This indicates that the flowback fluid not only mixes with formation brine, but also undergoes water-rock reactions with the formation matrix; the carbonate rocks in the shale reservoir are dolomitized. During dolomitization, Mg^{2+} partially substitutes for Ca^{2+} in the $CaCO_3$ lattice, converting calcite to dolomite. This process depletes Mg^{2+} from solution while releasing Ca^{2+}, resulting in the observed low-Mg^{2+} and relatively enriched Ca^{2+} characteristics of the flowback fluid. Divalent cations such as Ca^{2+} and Mg^{2+} are easy to precipitate, and reinjection without treatment will plug the cracks.

The change of salinity has certain rules on the same gas production platform of the Zheng'an block. The longer the flowback time is, the higher the salinity is. This suggests that the fracturing flowback fluid is a mixture of the injected fracturing fluid and shale formation brine. After the fracturing fluid is injected into the shale reservoir, the water-rock reaction will occur in the process of fracture formation and fluid migration, and the carbonate rocks (calcite and dolomite) in the shale reservoir will be dissolved and released, resulting in the change of ions in the water [23].

High COD is mainly due to the fact that the fracturing fluid in the Zheng'an shale gas block is mainly fresh water and slick water. In the preparation process, various additives such as surfactants, drag reducers, acids, gels, etc. are added. These additives are mostly toxic and difficult to remove, resulting in high COD. COD reflects the degree of water pollution by reducing substances. The higher the COD, the higher the organic pollution of water.

The content of dissolved oxygen, total iron and ferrous iron also has a great influence on the corrosion of downhole string and pipeline in gas wells. In the production of gas wells, the corrosion of tubing, downhole string and gas pipeline is affected by many factors. Combined with the field survey, it is found that the phenomenon of corrosion and scaling of downhole string is found in Anye 4 platform, Anye 1 platform and Anye 7 platform. One of the important factors causing this phenomenon is corrosive bacteria. Because the flowback fluid contains carbon-rich organic matter, it serves as a growth substrate supporting diverse microbial communities. Iron bacteria can produce a large amount of iron oxide deposition in a short time. Fe^{2+} is oxidized to Fe^{3+} and corrosion occurs through crevices. Mucus and iron bacteria produced by saprophytic bacteria are attached to pipe strings, equipment and gas pipelines, causing scaling. Sulfate-reducing bacteria are the most important bacteria in microbial corrosion. They produce black precipitated FeS in pipelines, pipe strings and ground equipment, which can lead to the blockage of pipelines and equipment. In addition, they can also corrode equipment, causing perforation of downhole pipe strings and pipelines, and ultimately reducing gas well production [24]. The diverse microbial communities detected in the Zheng'an block flowback fluids, including halotolerant bacteria and sulfate-reducing bacteria, are consistent with microbial profiles reported from other shale gas wastewater in the Sichuan Basin [21].

5.2 Treatment recommendations

Combined with the above research, the fracturing flowback fluid is mainly composed of fracturing injection fluid and formation brine. With the extension of flowback time, various ions also increase, and the water quality is unstable. The ions and salinity of flowback fluid in different gas wells are quite different. Therefore, biological treatment alone is insufficient for the flowback fluid due to its high salinity and complex chemical composition. In the exploration and development of Zheng'an shale gas in Guizhou, drilling, fracturing and other projects mainly give priority to the recycling of flowback fluid. In order to avoid the influence of various ion contents in the flowback fluid on the production of gas wells, it is necessary to treat and reuse the flowback fluid. In view of the characteristics of high COD and suspended solids in Zheng'an shale gas flowback fluid, a mature pretreatment process should be developed. Advanced oxidation methods such as ozone oxidation and electrocatalytic oxidation can be used to reduce the COD in the flowback fluid. Chemical flocculation can be used to remove suspended solids, solid impurities, etc. In the treatment process, Ca^{2+}, Fe^{2+}, Mg^{2+} and other metal ions should be removed as much as possible. Given the high concentrations of saprophytic bacteria and sulfate-reducing bacteria detected in the flowback fluid, biocides should be applied during both treatment and production operations to control bacterial growth. Flowback fluid intended for discharge must be treated to meet the applicable

Table 4. Comparison of major ions in Zheng'an Block flowback fluid with different discharge standards.

Water Sample / Standard (mg/L)	Na^+	Cl^-	SO_4^{2-}	Fe
Zheng'an Flowback Fluid (Range)	7370–27396	9000–43000	0	0.3–11.4
Agricultural Irrigation Water (GB 5084-2005)		350		
Surface Water Quality (GB 3838-2002)		250	250	0.3
Guizhou Province Pollution Discharge Standard (DB 52/864-2022)		250		1

emission standards, such as those listed in Table 4, before release. Therefore, it is necessary to detect the flowback fluid produced in shale gas exploration and development and adopt the corresponding treatment process. The substantial water consumption associated with hydraulic fracturing in the Sichuan Basin further underscores the importance of flowback fluid recycling for reducing the overall water footprint of shale gas development [25].

6 Conclusions

This study on shale gas flowback fluid in the Zheng'an Block, Guizhou, yields the following conclusions:

(1) The contents of Na^+, Ca^{2+}, Mg^{2+} and Cl^- in the flowback fluid of Zheng'an block in Guizhou are 7370–27396 mg/L, 299–480 mg/L, 86–162 mg/L and 9000–43000 mg/L, respectively. The characteristics of high Na^+ and Cl^- in the flowback fluid indicate that the salt content in the flowback fluid is high. With the extension of the flowback time, the higher the salinity is, indicating that it is mixed by the formation brine.

(2) The microorganisms in the backflow fluid include iron bacteria, saprophytic bacteria and sulfate-reducing bacteria. The content of saprophytic bacteria (TGB) ranges from 0 to $\geq$ 11,000 cells/mL, with an average of 3152 cells/mL. The content of sulfate-reducing bacteria (SRB) ranges from 0 to 1100 cells/mL, with an average of 276 cells/mL. The content of iron bacteria (FEB) ranges from 0 to 110 cells/mL, with an average of 10.9 cells/mL.

(3) The flowback fluid contains other pollutants, and the content of COD is more prominent. The content of COD is in the range of 0–9801 mg/L, with an average of 2740.57 mg/L. The main reason is that the fracturing fluid in the Zheng'an shale gas block is mainly clean water and slick water. In the preparation process, various additives such as surfactants, drag reducers, acids, and gels are added. Such additives are mostly toxic and difficult to remove, resulting in high COD. As a comprehensive index of the relative content of organic matter, the larger the COD value, the more polluted the water body.

(4) In the exploration and development of the Zheng'an shale gas in Guizhou, drilling, fracturing and other projects mainly give priority to the recycling of flowback fluid. In order to avoid the influence of various ion contents in the flowback fluid on the production of gas wells, it is necessary to treat and reuse the flowback fluid. Therefore, it is necessary to detect the flowback fluid produced in shale gas exploration and development and adopt a corresponding treatment process.

Data Availability Statement

Data will be made available on request.

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Conflicts of Interest

Fengying Yang and Xiaojun Zhu are affiliated with the Guizhou Shale Gas Exploration and Development Co., Ltd., Zunyi 563499, China; Zhongyun Chen is affiliated with the Guizhou Wujiang Shale Gas Exploration Co., Ltd., Zunyi 563400, China. The authors declare that these affiliations had no influence on the study design, data collection, analysis, interpretation, or the decision to publish, and that no other competing interests exist.

AI Use Statement

The authors declare that no generative AI was used in the preparation of this manuscript.

Ethical Approval and Consent to Participate

Not applicable.

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Fengying Yang , female, holds a Master's degree in Geology and works as an Assistant Engineer of Oil & Gas Exploration and Development. She is mainly engaged in shale gas geological exploration, development, and gas well dynamic analysis. (Email: yangfengying1122@163.com)

Zhongyun Chen , male, holds a Bachelor's degree in Resource Prospecting and works as a Senior Engineer of Oil & Gas Exploration and Development. He is mainly engaged in gas well dynamic analysis, unconventional natural gas development, and other related work. (Email: 2834627227@qq.com)

Xiaojun Zhu , male, holds a Bachelor's degree in Resource Prospecting Engineering and works as an Assistant Engineer of Oil & Gas Exploration and Development. He is mainly engaged in dynamic analysis and unconventional natural gas exploration and development. (Email: 1402445207@qq.com)