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RESEARCH PAPER

Inhibition performance and mechanism of Horsetail extract as shale stabilizer

BARATI Pezhman*, KESHTKAR Sadegh, AGHAJAFARI Amirhossein, SHAHBAZI Khalil, MOMENI Ali

Ahwaz Faculty of Petroleum Engineering, Petroleum University of Technology, Ahwaz 63431, Iran

Abstract: The Horsetail extract was used as shale stabilizer, its inhibition performance was studied by laboratory experiments and compared with potassium chloride and polyamine, and its anti-swelling mechanism was analyzed. Bentonite inhibition test, sodium bentonite sedimentation test, dynamic linear swelling test, and hot rolling cutting dispersion test were employed. The results show that: the bentonite is not capable of being hydrated or dispersed in solution with the Horsetail extract; the Horsetail extract can reduce the swelling of the bentonite and prevent disintegration and dispersion of cuttings in aqueous medium; the extract is well comparable and competitive with potassium chloride and polyamine in inhibition performance. The constituents of the Horsetail extract have active hydroxyls which are capable of forming hydrogen bounding with surfaces of bentonite particles, leading to decrease of the water absorption on bentonite particles' surfaces which results in bentonite swelling reduction. Besides having good anti-swelling ability, Horsetail extract is ecofriendly, readily available and inexpensive.

Key words: Horsetail extract; water-based drilling fluid; shale hydrated swelling; shale stabilizer; anti-swelling mechanism

Introduction

Shale makes up an enormous share of underground formations of oil-gas reservoirs. Because of consisting of active clays such as smectite and illite, shale faces with swelling and disintegration when in close proximity to water base drilling fluids. This swelling and disintegration lead to the washout of wellbore which results in sticking of drill string and bit balling during the drilling[1–2]. It may also cause well logging tools stuck when they are run into the hole. Moreover, it makes errors in reading of the tools and interpretation of logs[3]. That is why drilling engineers are to control and reduce this swelling and to do so, have come to use oil-based muds, which despite being expensive, have destructive effects on the environment[4–5]. Besides this sort of muds, salty muds (especially potassium chloride) are important to drilling engineers. Due to their high salt percentage, salty muds, despite making environmental problems while disposing, reduce the performance of other water-based mud additives[6–7]. Recently, amines and their derivatives have been remarkable for researchers as shale stabilizer which have limited applications and are toxic in many cases[8–9]. Thus, we decided to introduce a new application of herbal extracts in controlling shale swelling in water-based drilling fluids because they are ecofriendly, readily available and inexpensive. In this work, shale antiswelling properties of Equisetum arvense L. (Horsetail) extract have been investigated using different experiments of bentonite inhibition, bentonite sedimentation, dynamical linear swelling, hot rolling shale particle disintegration and adsorption measurement tests. At last, possible mechanism of Equisetum arvense L. extract has been explained according to its constituents and the experimental results.

1. Experiment

1.1. Materials

Equisetum arvense L. is a kind of herb from Equisetaceae family[10], and is usually known as Field Horsetail or Common Horsetail. This self-grown herb usually grows in wet places such as swamps, marshes and next to roads and rivers. It has been used as blood coagulant in Ancient Greek[11]. For the present work, Equisetum arvense L. extract was purchased from Ebnemasouyeh Pharmaceutical Company, Tehran, Iran, and it was brownish red. Extraction has been accomplished via water, and resulting powder is soluble in water and alcohol. Some weak acids such as siliceous acid exist copiously in this extract[11]. pH values for various concentrations of Equisetum arvense L. extract have been measured by Sartorios PP-20 pH meter and are plotted in Fig. 1, showing that the acidity of solution rises when this extract is solved in water.

Bentonite used in experiments has been supplied by Pars Drilling Fluids Company, Tehran, Iran. This bentonite is known as sodium bentonite due to its high percentage of sodium montmorillonite. Its composition consists of 65.5% of

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*** Corresponding author.** E-mail: putpezhman@yahoo.com

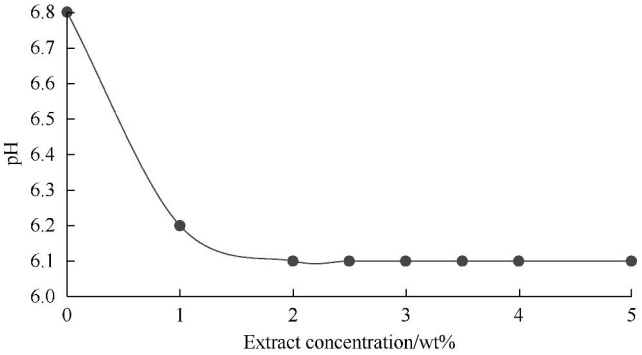

Fig. 1. pH of Equisetum arvense L. extract aqueous solution in different concentrations.

montmorillonite, 10.0% of feldspar, 8.0% of quartz, 8.0% of cristobalite, 3.0% of gypsum, 2.0% of illite, 2.0% of muscovite (mica), 1.0% of anorthite and 0.5% of calcite, all in weight percent (wt%). Its methylene blue capacity was determined as 0.7 mmol/g according to the API recommended practice of standard procedure for laboratory testing drilling fluids[12].

Drill cuttings used in this work were obtained from Asmari formation of Maroon oilfield in Southwest of Iran, well number 322, and in a depth of 3 446 m which has a methylene blue capacity of 16.5 mmol/g. Potassium chloride and sodium chloride have been supplied by Merck Company, Germany, and polyamine has been supplied by Pars Drilling Fluids Company, Tehran, Iran. All experimental materials have been used without any further purification operations.

1.2. Methodology

1.2.1. Bentonite hydration inhibition test

This test has been used to evaluate the inhibition potential of Equisetum arvense L. extract against the entrance of active clay minerals to the drilling mud and their hydration. In this test, at first, aqueous solutions were prepared from 0 and 4 wt% of the extract by means of magnetic stirrer. Then, a 3 wt% of bentonite was added to it periodically after 16 h of hot rolling at 71 °C (160 °F). Mixing time after adding new bentonite to the dispersion was 20 min[13]. Before adding new bentonite to this dispersion, its rheological properties, i.e. apparent viscosity (AV), plastic viscosity (PV), and yield point (YP) were obtained using the 35SA Fann rotational viscometer according to API recommended practice on the rheology and hydraulics of oil-well drilling fluids[14–15].

This test was kept on until the dispersion became so viscous such that its rheological properties could be measured. Also, inhibition potential of Equisetum arvense L. extract in 3 wt% concentration was compared with potassium chloride and polyamine which are two of the most common shale stabilizers in drilling industry.

1.2.2. Sodium bentonite sedimentation test

The sodium bentonite sedimentation test was used to measure the instability of clay minerals (dispersed clay particles) in inhibitive medium. To do so, at first, solutions of Equisetum arvense L. extract with 0–5 wt% concentrations were prepared. Then 0.25 g bentonite was added to 50 mL extract solutions. The solutions were then mixed by magnetic stirrer for 30 min in order to let the added bentonite disperse well in extract solution. Then the resulted dispersions were poured into glass test tubes having an internal length of 145 mm and an inner diameter of 10 mm. The lid was closed and they were held in test tube holder at atmospheric conditions and room temperature in static state. After 24 h, a visible and clear interface between sediment and supernatant was made up. Measuring the distance between this interface and the bottom of tube (h), and dividing it by internal length of tube (H), the ratio of h/H can be plotted based on different concentrations of the extract. This test was repeated again with potassium chloride in order to be compared with the performance of Equisetum arvense L.

1.2.3. Dynamic linear swelling test

Dynamic linear swelling apparatus was used to measure the linear swelling of bentonite wafers which were in touch with Equisetum arvense L. extract solution. In this test, 10 g bentonite has been placed inside hydraulic compactor apparatus under a 41.37 MPa (6000 psi) pressure for 30 min, and bentonite wafers with a diameter of 28.3 mm have been prepared. After measuring initial thickness of wafers using caliper (with 0.01 mm accuracy), they were placed inside linear swelling cup assembly which is located on hot plate stirrer. Dial indicator with an accuracy of 0.01 mm was installed on them to measure the bentonite wafer thickness increase. After zeroing the dial indicator, the testing fluid was poured into the cup and the increase of bentonite wafer thickness within 24 h was recorded (once every 10 min until 3 hours, and then once every 60 min until 24 h) after setting the temperature of hot plate stirrer. Then, the swelling percentage of wafers (ratio of bentonite wafers' thickness increase to its initial thickness) was calculated.

The performance of Equisetum arvense L. extract was compared with common shale stabilizers, i.e., potassium chloride and polyamine, in 3 wt% concentration. The tests were repeated at both temperatures of 21 °C (70 °F) and 71 °C (160 °F) to investigate the temperature impact on swelling of bentonite wafers.

1.2.4. Hot rolling recovery test

The test was performed according to API recommended practice of standard procedure for laboratory testing drilling fluids[12], to evaluate the shale antiswelling potential of Equisetum arvense L. extract, in comparison with potassium chloride and polyamine as two common shale stabilizers. In this test, at first, 30 g drill cuttings with sizes varying between 2 and 4 mm — which had been formerly dried in oven for 24 h at 104 °C (220 °F) — was added to the cells of hot rolling oven apparatus (with the speed of 22 r/min) which contains 350 mL tested fluid. Then, it was rolled for 16 h at 71 °C (160