GROUNDWATER PROTECTION DURING WELLBORE DRILLING

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Abstract - During drilling operations special attention must be addressed to the adequate design (proper composition) of the mud used during drilling, especially the one used during the drilling for running surface casing that passes through the aquifer. Also, in next phase it is necessary to properly design the cement slurry, since casing must be cemented in place, in order to insulate the underground sources of drinking water (USDW) with quality cement sheath. Although during drilling there is a risk of groundwater pollution, it is necessary to take into account the pollution that can occur many years after the well is drilled, during the use of the well for various purposes such as production or injection of fluids, as well as after the well is abandoned. This paper will present the possible pollution of groundwater during drilling and possible migration paths of fluids into angroundwater duringthe entire lifetime of the well.

Keywords - Drilling, Mud, Cementing, Migration Paths of Fluids Into An Aquifer, Groundwater Protection

I. INTRODUCTION

Wells are drilled using a drilling rig that is mounted on the surface. The set of tools used to drill the well consists of a drill bit, drill collars and drill pipes. Since it is difficultand often impractical to drill a well that will have the same diameter from the surface to the bottom, the wells are drilled in sections in such a way that the first section that passes through the groundwater is drilled with a drill bit of the largest diameter, and when the desired depth is reached, it is necessary to install a casing that will isolate the groundwater. After installing the casing, it must be cemented with cement slurry of the appropriate composition, which after some time turns into a solid material and represents a barrier to potential contamination of drinking water. The drilling process takes place in the same way by alternately drilling the rock and installing and cementing casing until the final depth of the well is reached. Also, during the drilling, a large number of drilled cuttings is generated, which must be brought to the surface, and this is made possible by the use of drilling mud that is circulated from the surface into the wellbore through a drilling string and drill bit at the bottom, and returned to the surface through the annular space between the drill string and the wellbore walls. The separation of drilled cuttings from the liquid phase takes place on the surface,after which the drilled cuttings are disposed of, while the mud is circulated back into the wellbore (Figure 1).

Depending on the continuous phase, drilling mud is divided into water-based drilling mud (fresh water or sea water) and non-aqueous drilling mud (including oil-based and synthetic mud) (IOGP, 2016). There are a number of reasons for mud usage during drilling operations. These are: (1) cleaning the working surfaces of the drilling tools (drilling bit for example) and the hole bottom, (2) removing drilled cuttings from the wellbore, (3) cooling and lubricating the drill bit and drill string, (4) primary well control mechanism, (5) prevention of swelling and collapse of the wellbore walls, (6) mud cake formation on porous and permeable rocks, (7) retention of drilled cuttings in a floating state after the circulation interruption, (8) prevention of permeability reduction in drilled underground reservoirs, (9) corrosion prevention of drilling string and cemented casing with corrosion-induced premature fatigue of material, (10) enabling the necessary measurements and other operations during drilling (Pašić et al, 2020; Medhi et al., 2020; Ikram et al., 2021; Li et al., 2021).

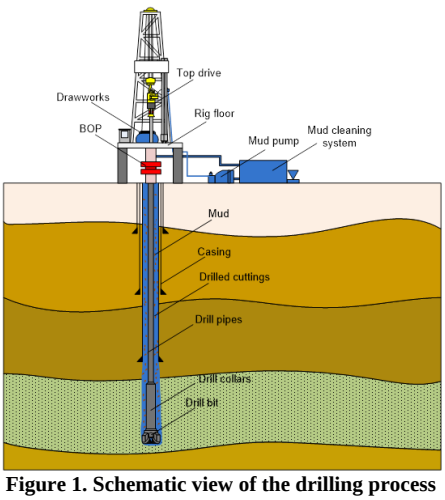


Figure 1. Schematic view of the drilling process

Drilling mud is prepared by adding various additives to the continuous phase (water, oil, synthetic compounds) to adjust the desired mud properties. The oil&gas industry has developed a large number of additives that are used to modify the physical and chemical properties of mud to help overcome different wellbore problems. Figure 2 shows the most common additives that are added to water-based muds, oil-based and synthetic muds. The additive that is added in the highest concentration is the barite (e.g. in the case of water-based muds, 14% by mass, and in

the case of oil-based and synthetic muds, 33% by mass), a well-known weightening additive (IOGP, 2016). Additives that are added to water-based muds to adjust the rheological properties are following: (1) viscosifiers, which include clays (bentonite) or polymers (e.g. xanthan gum, guar gum, acrylamides) and (2) dispersants (e.g. lignosulfonates, lignites, tannins, lignins), while salt water, emulsifiers and viscosifiers are added to mud based on oil or synthetic fluid.

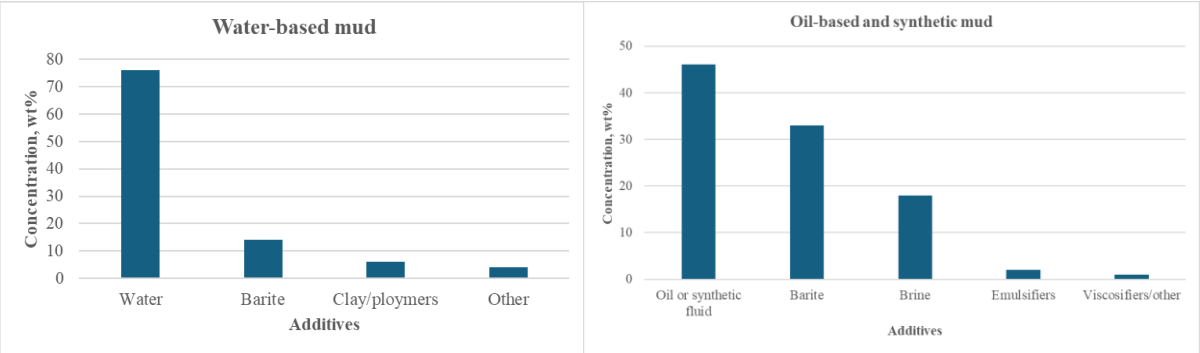


Figure 2. The most common additives that are added to water-based muds and oil-based and synthetic muds (modified according to IOGP, 2016)

II. POSSIBLE INFLUENCE OF DRILLING MUD ADDITIVES ON THE ENVIRONMENT

Most of the additives are natural and can be found in the environment, so negative impact on the environment is eliminated. However, some of the additives may contain potentially toxic compounds that must be taken into account. Some of the pollutants that can have a negative impact on the environment are: biocides, oil, well completion and stimulation fluids, corrosion inhibitors, reservoir fluids (oil or formation water) and some chemical additives in mud (Patin, 2004; Onwukwe and Nwakaudu, 2012). Many of the wastes associated with wellbore construction have the potential to adversely affect the environment. The physical and chemical properties of waste indicate its ability to influence the environment. The most common measure of potential environmental impact is its toxicity. Table 1 shows the types of waste from drilling operations and their components that can have a negative impact on the environment. The possible impact depends primarily on the chemical composition of the waste, its concentration after release into the environment and the length of exposure (Onwukwe and Nwakaudu, 2012).

Type of waste	Main components	Components that can have a negative impact on the environment
Lubricants in mud	Lubricating oil, grease	Heavy metals, organic substances
Spacers	Mineral oil, detergents, surfactant	Hydrocarbons, alcohols, aromatics
Water-based waste mud (includes salt water)	Complete mud, mineral oil, biodegradable substances	Heavy metals, inorganic salts, biocides, hydrocarbons, drilled cuttings, organic substances
Drilled cuttings from water-based mud	Drilled cuttings, mineral oil applied in water-based mud	Heavy metals, inorganic salts, biocides, hydrocarbons, drilled cuttings
Oil-based waste mud	Mineral oil	Hydrocarbons, heavy metals, inorganic salts, drilled cuttings, surfactant, organic substances
Drilled cuttings from oil-based mud	Drilled cuttings, mineral oil	Heavy metals, inorganic salts, hydrocarbons, drilled cuttings
Additives for adjusting mud properties	Bentonite, barite, viscosifiers, thinners, lost circulation materials, special additives	Heavy metals, hydrocarbons, organic substances, drilled cuttings
Special additives	H_2S cleaners, antifoaming agents	Zinc carbonates, iron oxides, hydrocarbons, silicone oils, potassium salts, radioactive material

Table 1.Types of waste from drilling operation and ecologically significant components that can have a negative impact on the environment (Bashat, 2002; Onwukwe i Nwakaudu, 2012)

Heavy metals can be found in muds in two cases: (1) many of them occur naturally in the underground formations and enter in the mud during drilling, or (2) they are found as constituents of additives used to adjust mud properties (Enty, 2011). The most frequently found metals are barium, which originates from the barite, and chromium from Cr-lignosulfonate, that is used as dispersant in mud. Heavy metals of particular importance that occur in nature are arsenic, barium, cadmium, chromium, lead and mercury (Enty, 2011). The toxicity of many heavy metals lies in their effect on enzymes, which limits normal biochemical processes in cells. If mud containing heavy metals is deposited in surface pits that are not protected by an impermeable barrier, heavy metals can mix with the soil and contaminate the groundwater. Unlike most organic pollutants, heavy metals are difficult to extract from groundwater because they are not biodegradable, and if such water is used, it can cause serious consequences for humans, flora and fauna (Zoveidavianpoor et al., 2012). The use of such additives are decreasing, considering that the environmental regulations are getting rigorous in broader part of world.

III. POSSIBLE MIGRATION PATHS OF FLUIDS INTO AN AQUIFER DURING DRILLING

Considering that during the drilling of the first (subsurface) section, the drilling mud is in contact with the rocks that contain groundwater, there is the greatest chance for its pollution, primarily because the filtrate from the mud can penetrate into the zone with drinking water. The mud itself used for drilling this section should consist of additives that are environmentally acceptable, and that section should be drilled as soon as possible in order to install a casing. After installing the casing, it must be cemented using cement slurry, which, like drilling mud, must be environmentally friendly and must not contain polluting additives (Figure 3).

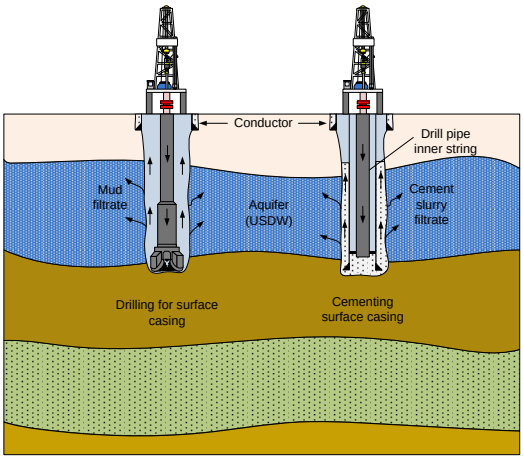


Figure 3. Possible migration paths of fluids during drilling (left), a during cementing phase (right)

IV. POSSIBLE MIGRATION PATHS OF FLUIDS INTO AN AQUIFER AFTER WELLBORE IS DRILLED

Each well is drilled with a purpose and is expected to be used for various operations over a long period of time. In the beginning, the wells are mostly used as hydrocarbon or geothermal water production wells, and over time they can be converted into injection wells. Injection of waste slurry into suitable underground formation became an ecologically proven method three decades ago, but also an economically viable solution for disposal of waste from oil and gas exploration and production activities in underground formations, especially for remote and ecologically sensitive areas (Fragachán et al., 2006 ; Ronderos and Ovalle, 2010; Ji et al., 2013). According to the available literature, most deep underground waste slurry injections were conducted through tubulars (tubing string), which is a logical choice considering safety, economic and technological reasons (Gaurina-Međimurec et al., 2020). As most aquifers are not deeper than 200 m (Ferguson et al., 2018), for adequate groundwater protection injection wells must be equipped with surface casing cemented from the wellhead. After the well is no longer commercially viable for any operation it must be abandoned and the surface return to its original form (Gaurina-Međimurec and Pašić, 2011).

One of the most important tasks is to prevent any unwanted movement of the pollution back to the surface or to underground potable water sources. With the development of technology it is possible to drill a wellbore in a safe and economically efficient way, without impacting groundwater. In order to achieve this, it is necessary to ensure the internal and external mechanical integrity of the well so there is no possibility for significant leakage through the tubing, casing or other downhole equipment installed within the well and there is no significant movement of the pollution behind the well to groundwater zone (Figure 4).

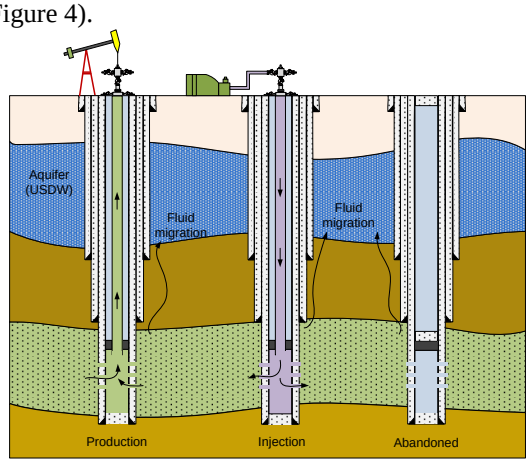


Figure 4. Possible migration paths of fluids during production, injection or after the well has been abandoned

V. CONCLUSION

Although the wellbore drilling through formations containing underground sources of drinking water is a challenge, every year the industry invests considerable efforts to ensure that this process does not lead to contamination at any stage, from the wellbore drilling to its abandonment. The usage of such additives which can be dangerous is significantly decreased, considering that the environmental regulations are getting rigorous in broader part of world. In most cases, the concentrations recorded during drilling are insignificant, therefore the impact on the environment is generally observed only after a longer exposure to the waste, which can be case during production or injection. However, with today's state of technology it is possible to monitor more and more parameters that are essential for the safe well drilling through the selected underground formation so a further decrease in the risk associated with performing this type of operation can be expected in the future.

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