Means of atmospheric air pollution reduction during drilling wells

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Abstract. The process of drilling oil and gas wells is the source of air pollution through drilling mud evaporation containing hazardous chemical substances. The constructive solution for cleaning device of downhole tool that contains elements covering tube and clean the surface from the mud in the process of rising from the well is offered. Inside the device is filled with magnetic fluid containing the substance neutralizing hazardous substances. The use of the equipment proposed will make it possible to avoid penetration of harmful substances into the environment and to escape the harmful effects of aggressive substances for staff health and increase rig’s fire safety.

1. Introduction
Oil and gas extraction is the source of constant environmental pollution. The most difficult process in oil and gas industry is drilling. There are a number of potential sources of pollution on the rig. One of the main is pump-circulation system of the drilling rig, which is associated with flushing wells drilled. To wash the wells with the drilling mud it is used with appropriate rheological properties ensuring perfect cleaning bottom hole from rocks and optimum hydraulics bit etc. [1]. With this purpose, drilling mud is added to a variety of chemical components that may have high toxicity.

At the exit of the wells solution may be saturated with hydrogen sulfide, radioactive elements and other substances hazardous to staff health and the environment [2].

Drilling pollution can be divided into separate stages [3]:
- washing wells during drilling, drilling fluid leakage from the high temperature wells, revenues in its cleaning unit, where the intense evaporation is taking place and its transportation to the container;
- lifting drilling tool 2-6 thousand meters or more from the well with a layer of mud outside drilling string.

Reducing exposure to harmful vapors personnel and the environment during the first phase is proposed to implement by using sealed and modernized equipment items of pump circulation system described in [4]. Tackling pollution mud as a result of lifting drilling tools needs analyzing processes that occur during the drilling equipment that purifies downhole tool.
2. Investigation of drilling mud evaporation processes

While deep hole drilling the amount of water used increases and drilling mud heavier are used: barytic and hematite. Oil-based drilling fluids are very dangerous for the environment. Also different organic and non-organic toxic chemical substances are used [5]. That is why it is important to conduct investigation and analysis of every possible situations of drilling fluid and its evaporations penetration into environment.

Evaporation speed depends on many internal and external factors such as evaporating material, temperature of evaporation and mud viscosity, temperature and movement of the air around. Thus, for example the temperature of drilling of bore hole walls increases with the increase of depth. The heat transmitted to the bore hole walls causes drilling fluid heating. When drilling fluid meets treatment elements its temperature may be rather high which intensifies the evaporating process [6].

The evaporating process has two main stages: molecular processes at interface border, that is molecular emission from liquid into gas condition; molecular substance transport at gas stage. That is why if vapours are rapidly taken away from the surface (the presence of wind) condensation is practically minimal and the evaporation is maximum [7].

Drilling fluid may penetrate the environment during drilling tool round trips (DTRT). Namely during drillstring lifting and putting stands on pipe setbacks using their fingers there leaves a layer of drilling fluid which evaporates into atmosphere. Hard particles that are left on drilling pipes may be spread by wind around the site. While borehole drilling DTRT are repeated every 2-4 days. Especially often DTRT are conducted during liquidation borehole complications. In this case DTRT are conducted several times within 1 day.

U-bends at the drill-pipe breaks-off are also possible during drillstring lifting, which means that the leakage under drilling fluid pressure from the pipe lifted above the rotor, namely from the stand (the length of the stand may be 24-36-37 m). The stand consists of several separate drilling pipes. The U-bends mainly occur while drilling with core sample collection, drilling by breasting arrangements, salt layers development which cause drilling fluid thickening at annular space.

The investigation has been conducted at a proper borehole #72 of Letnyansky deposit (West Ukraine) equipped by BU-75BpE drilling rig. The geological-technical order (GTO) data: project depth 1620m; time cycle – 156,2; mode of drilling – rotor; pipes diameter 102mm.

The daily cyclograms during the hole period of drilling of the borehole #72 of Letnyansky deposit have been analyzed. It made it possible to calculate the drilling fluid volume at the outer surface of the drilling pipes at outer pipe diameter 0.102 mm. and it turned out that during GTO for the time period under study about 10.5m$^3$ of the drilling fluid evaporate into the environment.

With the use of Matlab software the mathematical modeling process of DF evaporation on the site close to DR has been conducted and the impact of its primary factors on concentration distribution [8].

Reference data give us respectful DF components features given in Table 1. The calculation results confirm the highest intensity owing to the highest partial pressure has benzene $G_2 = 35,122$ g/s which permits quicker evaporation. The evaporation time is less than 17 hours. The least intensity ($G_3 = 4,7442$ g/s) and the longest evaporation time (about 50 hours) is that of the toluene. Thus, a conclusion can be made that under given circumstances the whole fluid evaporates within the period of about 50 hours.

| Feature          | Fluid component | Water | Benzene | Toluene |
|------------------|-----------------|-------|---------|---------|
| Relative molecular mass | 18,015           | 78,10 | 92,14   |
| Boiling temperature, °C | 100              | 80,3  | 110,8   |
| Antoine constants | $A = 7,9608$   | $A = 6,912$ | $A = 6,953$ |
|                  | $B = 1678$    | $B = 1214,6$ | $B = 1343,9$ |
|                  | $C = 230$     | $C = 221,2$  | $C = 219$  |
Figure 1. Dependence of evaporation intensity from velocity

Figure 2. Dependence on evaporation intensity from DF temperature

Figure 1 shows the dependence of evaporation intensity from velocity for every component of the fluid. As the velocity increases so does the evaporation intensity which is experimentally confirmed.

The wind tears off the molecules from the layer which is the nearest to the fluid surface and thus increasing the intensity of evaporation. Figure 2 shows the dependence of evaporation intensity from the fluid temperature. As the temperature increases so does the evaporation intensity as the amount of molecules able to cross phase boundary increases.

As modeling results show the highest pollution intensity is that of benzene. It is due to its high partial pressure above the DF surface and bigger weight fraction compared to other fluid components. In case of benzene evaporation just from the surface of lifted drilling strings the highest concentration is 0.036 mg/m³ and from sludge pit – 0.014 mg/m³.

To analyze the transactions that occur while drilling a well for the entire period, the analysis of daily diagram of individual wells is conducted. Probable values of volumes of drilling mud on the outside of the drill pipe and the inner cavities at various sizes in the drill pipe (Table 2). This table does not take into account the geometric dimensions of interlocks, adapters, weighted drill pipes and other elements of the layout of the bottom of the drill string. Taken as a basis in the solution layer thickness of 1 mm on the outer surface drill pipes, but depending on its viscosity and other indicators of film thickness can vary.

At the absence of devices for cleaning downhole tool from drilling fluid that comes from the wells, the pollution of floors, equipment and grounds well solution of different categories of danger that can be dangerous to staff health, the environment, and create a fire hazard.

| №  | The outer diameter drill pipe D₀, mm (m) | In one linear meter of drill pipe | The area of the outer surface S, m² | Volume of thickness 1 mm of mud on the outside V₀, m³ |
|----|--------------------------------------|---------------------------------|---------------------------------|---------------------------------|
| 1  | 89 (0,089)                           |                                 | 0,28                            | 0,28·10⁻³                        |
| 2  | 102(0,102)                           |                                 | 0,32                            | 0,32·10⁻³                        |
| 3  | 114(0,114)                           |                                 | 0,36                            | 0,36·10⁻³                        |
| 4  | 127(0,127)                           |                                 | 0,40                            | 0,40·10⁻³                        |
| 5  | 140(0,140)                           |                                 | 0,44                            | 0,44·10⁻³                        |
Figure 3 shows an example of a homemade pipe cleaner is not effectively cleaning the outer surface of the drill pipe. Figure 4 shows a layer of mud that remains on the surface of pipes that can evaporate into the air when lifting the boring tool and in the drill string during round-lifting operations.

![Figure 3. Homemade pipes cleaner](image1)

![Figure 4. Layer of mud in the drilling string](image2)

Figure 5 shows graphic dependences characterizing the volume of mud that remains on the outer surface of the pipe when the liquid layer thickness is 1 mm. So when the well is drilled to a depth of 4000m and over the negative impact of the above mentioned factors increases significantly.

![Figure 5. Graphical dependence of volume of drilling mud from the well depth](image3)
The absence of the drilling tools equipment from flushing fluid causes rig floor pollution, equipment and the rig territory, this fluid can be harmful for staff’s health, for environment and fire hazardous. Nowadays the drilling rigs use tools for cleaning drilling pipes surface but in terms of design they are not perfect (as well as self-made ones) and there are no clear rules so as to their application and in case U-bends occur the whole drilling rig is polluted.

3. Drilling fluid cleaning tool
The existing equipment has some disadvantages:
- quick wearing out of the elastic elements at the point of contact with the surface, is cleaned;
- bad purification, as a result of complex forms a self-cleaning surface, as the elastic elements are not able to communicate with all the complicated surface;
- unsuitability for cleaning tool having variable cross-sections.

To reduce ingress of pollutants into the environment arising when lifting drilling tools and of drilling mud evaporation from the outer surface drill pipes offer a constructive solution purification equipment block of drilling mud and device for cleaning the downhole tool.

The based invention is the task of improving the reliability and efficiency of the device by preventing damage treatment elements, improving cleaning tool with complex surface shapes, as well as the ability to neutralize hazardous substances. The proposed device [9] can be used in drilling and repairing wells for cleaning the outside of downhole tools (drill pipe, tubing, rods, cables, etc.) during its recovery from the well.

Figure 6 shows a construction of the device for cleaning the downhole tool. The device consists of a housing 1 inside which is the casing 2 of non-magnetic material, which is cleaning magnet system consisting of magnets 3 and 4 magnetic circuits.

The lower part of body 1 attached to its mechanical cleaning element, consisting of a flange 5, a set of flexible wires 6 and intermediate washers 7, and on top of the end of the body 1 the tank 8 is installed of magnetic fluid 9 closed overhead mechanical purification element consisting of two rings 10 between which elastic wires 11 are fixed. The inner surface magnetic circuits 4 magnetic fluid is held a magnetic force field 12 that occurs between magnetic circuits and downhole tool 13.

Figure 6. Scheme of the device for cleaning downhole tool
The device operates as follows. The bottom 7 and top 10 are pre-installed in the device of the passage opening scrapers cleansing elements 6 and 11, which correspond to the diameter of the downhole tool 13. The device is set on the estuary of the well. Tools pass through the magnetic cavity 12, tank 8 and scrapers 7 and 10. This magnetic liquid 9 with containing neutralizing substance, which filled cavity 12 located in the direction of magnetic field lines and tightly covers the surface of the tool of any shape around the perimeter and erased mud. Neutralizing liquid, which is part of the magnetic fluid moisturizes and effectively purifies and neutralizes the surface of the tool from pollution and toxic substances. This intensifies the process of neutralizing toxic substances such as hydrogen sulphide, as under the influence of the magnetic field of the deformation and rupture of hydrogen bonds in the structure of toxic substances. The presence of tanks 8 with magnetic fluid allows to adjust the volume of magnetic fluid in the cavity of the tool when cleaning different profile when changing diameter of the tool is to be cleansed such drill column with locks. When moving the downhole tool through elastic wire scrapers 6 and 11, the tool is subjected to final cleaning from stuck magnetic fluid residues.

4. Conclusions
The approximate values of drilling mud volume on the outer surface of drilling pipes and their inner cavity have calculated. Recommendations that would reduce the ingress of mud on the environment while lowering gear works are proposed.

Taking into account all the above-mentioned it is necessary to recommend the obligatory implementation of the tools for high-quality cleaning of drilling pipes that are being lifted from a borehole. It may ensure considerate decrease in drilling fluids evaporation and the penetration of harmful substances into the environment. The structural analysis of drilling fluids evaporation and their movement after emitting the hole along the open part of pumping-circulating system showed the acuteness of the problem of drilling fluid evaporation into the atmosphere and carrying out further experiments.

Using the proposed equipment will avoid harmful substances into the environment, prevent harmful effects of aggressive substances on health personnel and increase fire safety rig.

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