

Effect of the HDD drilling mud on the environment

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Abstract: Horizontal Directional Drilling (HDD) is a trenchless method commonly used for laying various types of pipelines and cables. It is a common way of routing a technological line from one point to another by directional drilling under obstacles or in ecologically sensitive areas. The HDD can be used, for example, under rivers, roads or slopes where conventional excavation technologies would not be cost effective, reliable or may be environmentally invasive. One of the important elements influencing the success of horizontal directional drilling is a drilling fluid appropriately selected for the drilling conditions. The mentioned drilling fluid may, however, be a threat to the environment, therefore, in order to prevent it, it must be properly stored and disposed of.

Keywords: HDD, drilling mud, HDD technology

WPLYW PŁUCZEK DO WIERCEŃ HDD NA ŚRODOWISKO

Streszczenie: Horyzontalne przewiertory kierunkowe (HDD) to beżwykopowa metoda stosowana do układania różnego rodzaju rurociągów oraz kabli. Jest to powszechny sposób prowadzenia linii uzbrojenia z jednego punktu do drugiego poprzez odwiertory kierunkowe pod przeszkodami lub na obszarach wrażliwych ekologicznie. Technologia HDD może być używana na przykład pod rzekami, drogami lub zboczami, gdzie konwencjonalne technologie wykopów nie byłyby opłacalne, niezawodne lub mogłyby być inwazyjne dla środowiska. Jednym z ważnych elementów wpływających na powodzenie poziomych przewiertów kierunkowych jest odpowiednio dobrana do warunków wiercenia płuczka wiertnicza. Wspomniana płuczka wiertnicza może jednak stanowić zagrożenie dla środowiska, dlatego aby temu zapobiec należy ją odpowiednio dobierać, przechowywać i utylizować.

Słowa kluczowe: HDD, płuczka wiertnicza, technologia HDD

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1. Introduction

The HDD method is widely used in the construction of pipelines for the transport of gas, oil, water and sewage as well as communication and electric cables. Used for the first time to cross the river, it is now used for collision-free avoidance of all kinds of obstacles, wherever the use of classic methods is impossible or too expensive, or unacceptable due to interference with the natural environment.

Process of making HDD consists of the following stages (Wiśniowski and Ziaja 2007):

- drilling the pilot hole of author's contribution to create the paper,
- return boring (single or multiple),
- pipeline installation.

Drilling a pilot hole is the most important phase of making a hole. The pilot hole is made according to the assumed trajectory design (Fig. 1). Asymmetrical monitor borer is used as a digging tool in soils and poorly compacted rocks.

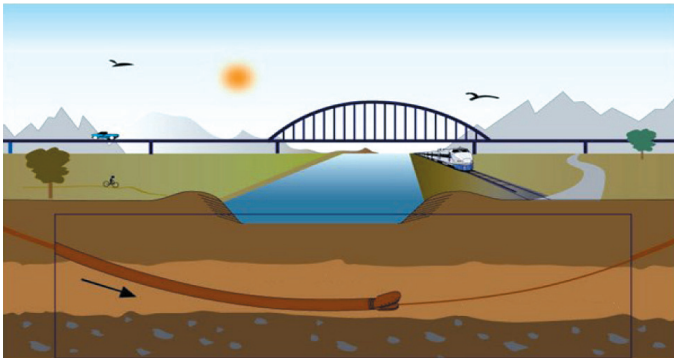


Fig. 1. Pilot hole drilling

Source: Janicki (2012)

The trajectory control of the axis of the drilled hole consists of continuous or periodic measurement and verification of the position of the probe located in the antimagnetic connector, located directly behind the drilling tool. For this purpose, surface radiometric or subsurface cable or cable-free telemetry navigation systems are used. Correction of the drilling direction is achieved by turning the drill rods by the angle corresponding to the expected change.

To achieve the predicted final diameter, the borehole is widened one or more times. After the pilot hole is made, a cutting or biting reamer is mounted in place of the

drilling tool for the drilling rods located in the drilling hole. By pulling the reamer into the pilot hole, the diameter of the existing borehole increases (Fig. 2).

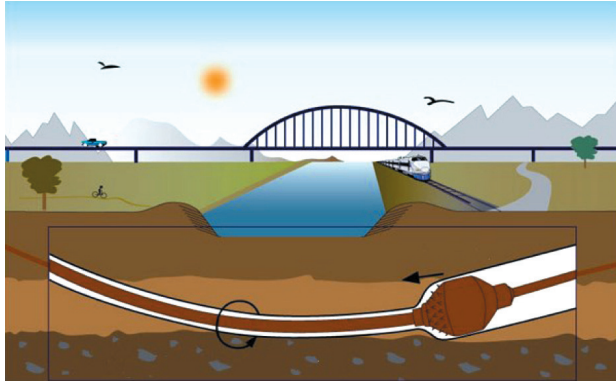


Fig. 2. Boring
Source: Janicki (2012)

During the process of widening the hole behind the reamer, the flushing pipes are successively tightened to enable subsequent stages of widening or pulling in the casing pipe (Wiśniowski and Ziaja 2007).

The final stage of the controlled horizontal drilling is to pull in the casing pipe (Fig. 3). For this purpose, a reamer, a rotary connector and a pulling head with retractable pipe are screwed to the drill string in the hole.

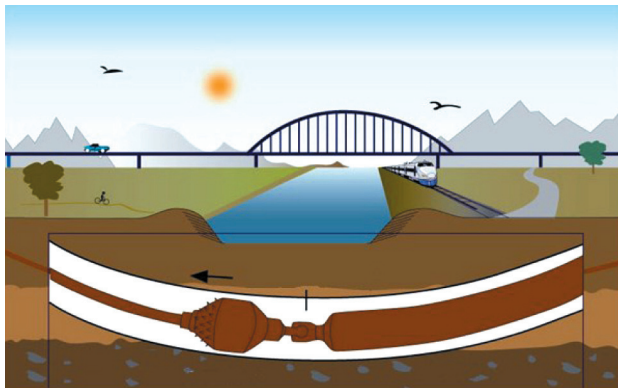


Fig. 3. Pipeline installation
Source: Janicki (2012)

The task of the rotary connector (swivel) is to prevent the transfer of rotation and torque from the drilling rods to the retractable casing pipe.

2. Advantages and limitations of HDD technology

HDD drills have numerous advantages, which include (Rojek and Wysocki 2010):

- slight interference in the natural environment,
- the ability to perform work in specially protected areas,
- ensuring full protection for the pipeline,
- reduced project execution time,
- HDD installations can be implemented in practice throughout the year,
- small interference in neighboring infrastructure,
- greater durability of electrical and telecommunications networks compared to overhead lines,
- fully predictable investment duration.

HDD, like any technology, has limitations. They result from the possibility of buckling of drill pipes and the installed pipeline, the length of the borehole, the number of direction changes, the accuracy of measurements during drilling, equipment parameters, wall stability of the hole made, the efficiency of cleaning the hole from drill cuttings and the friction of the pipe in the hole (Surmacz and Popielski 2007).

Therefore, if the works are carried out improperly, then there may be threats to the natural environment. For example, threats include the possibility of pollution within the drilling rig of the earth surface and groundwater with technological means used to prepare muds, noise emissions from drilling rigs, emissions of pollutants into the atmospheric air as well as temporary deprivation of areas occupied by the drilling rig and access roads to perform normal functions (Macuda and Marchel 2011).

The group of dangers also includes sinkholes that occur during horizontal drilling under roads and railroad tracks and tramway, where there are dynamic loads including heavy traffic. This is because in the process of boring the hole, taking into account the geology and the number of passes to the required diameter, the soil structure is also destroyed beyond the predicted diameter, e.g. by blurring with a mud stream during drilling or rinsing the hole. This phenomenon occurs especially in soils prone to blur and can lead to uncontrolled formation of large voids.

In addition to the threat caused by subsidence, voids are a new drainage path through groundwater, causing further blurring and enlargement of voids along the borehole. The effects of this process can occur long after the construction is completed, and their rapid course is most pronounced when the borehole ran under rigid objects, which are buildings, roads, and railroad tracks. Leaving empty space around the pipe can create many problems when crossing under water and rivers. Water seepage through the overburden soil layer can cause multiple problems. For example, after drilling under flood embankments, there can be seepage after, causing flooding, espe-

cially at different levels of entry and exit points of the drilling being performed (Kuliczowska and Kuliczowski 2011, Janicki 2012).

When trenching begins, drilling tools may collapse in low-load soils. Such situations occur when heavy drilling tools are used in weak centers, mining damage areas or in the vicinity of existing underground networks (Zwierzchnowska 2003).

Another danger during horizontal drilling is scrubber escaping. They are formed as a result of pressure exceeding the layer overburden by pressure in the annular space between the drill string and the borehole wall, which in turn contributes to the phenomenon of fracturing the surrounding layers. This can lead to surface scrubbing outflows at points other than expected or to deep sinking into surrounding formations (Janicki 2012)

Leaching the scrubber carries environmental hazards, as even small amounts of it entering the drilled aquifers may affect the quality of usable aquifers.

The next issue is noise, which when reaching high scale undoubtedly negatively affects animals and people. The noise during drilling operations is mainly generated by power generators, drilling motors and mud pumps, as well as vibrating screens. Generator sets are usually located in closed rooms with walls with low sound insulation, while drive motors and mud pumps are completely or partially covered with a carport or partly enclosed. Vibrating screens are generally completely exposed (Macuda and Marchel 2011). Propulsion engines produce high power, and thus contribute not only to the formation of noise, but also to local deterioration of air quality.

3. Drilling mud

The huge impact on the success of directional drilling is correctly selected for drilling conditions of the drilling mud (Rojek and Wysocki 2010). When performing Horizontal Directional Drilling, the scrubber performs many functions, which may include (INSTDOM website, n.d.):

- soil softening,
- drill cooling,
- stabilization of the hole walls,
- transport of cuttings,
- keeping cuttings suspended.

To this end, the drilling mud should have a low viscosity and a relatively high flow limit. Due to the horizontal direction of drilling, an important aspect is also ensuring adequate lubricity of the drilling fluid.

In works involving various trenchless techniques and technologies, which HDD drilling undoubtedly include, drilling muds were used, which are most often suspensions of bentonites, activated by means of chemicals (Rojek and Wysocki 2010). It should be mentioned that the chemical compounds added to bentonites (commercial products) are a trade secret, therefore they are not given in the product characteristics.

Drilling mud as mentioned is an aqueous solution of various types of bentonites and enriching additives. During the first stage, which is pilot drilling, the mud moistens the drill rod and the wall of the hole, cools the drill with the nearby control system probe, removes the resulting drill cuttings by rinsing, fills, stabilizes and seals the hole, and significantly reduces the risk of cavities the hole around the drill and its rod (drill pipes).

In the stage of widening the hole and the pipeline installation itself, the drilling mud reduces the risk of jamming the reamer or the pipelines being installed. Accurate geological exploration allows for proper selection of drilling mud recipe in order to best use its properties in drilling conditions (Janicki 2012).

When selecting chemical compositions in the development of drilling fluids, often do not take into account their impact on the environment, but mainly their impact on technological parameters of drilling and ensure the stability of the walls of the borehole. Materials and chemicals present in the composition of drilling fluids should be adapted to the general requirements of environmental protection, so that as little as possible accounted for him risk (Zima 2012).

By carrying out ongoing physical and chemical tests of the resulting waste, it is possible to determine the degree of their toxicity to the aquatic environment and to develop appropriate preventive measures to reduce the possibility of contamination of drinking water horizons (Macuda and Marchel 2011).

When drilling, depending on the depth and bored layers, two to three types of water-dispersion drilling muds are most often used (Steliga and Uliasz 2012):

- bentonite,
- clay free,
- polymer with properties limiting the hydration of clay shale rocks.

Bentonite is the basic component of the clay mud. Bentonite as a structure-forming component (thickener). However, in the silentless mud, the role of thickener is played by the XCD biopolymer, highly viscous organic polymers of plant origin or mixtures of these agents.

Organic, inorganic chemicals and mud materials are used to prepare and regulate the properties of drilling muds when drilling a hole. However, these agents are the main source of their pollution, due to the different biodegradability and the degree of their toxicity (Steliga and Uliasz 2012). Chemicals include, for example, polymer

inhibitors: PHPA, PG 1 PG 2. On the basis of the type of hole muds, which include bentonite, polymer-potassium, glycol-potassium (Fig. 4) and the mentioned inhibitors, chemicals contained in it (Fig. 5), a toxicity test was performed.

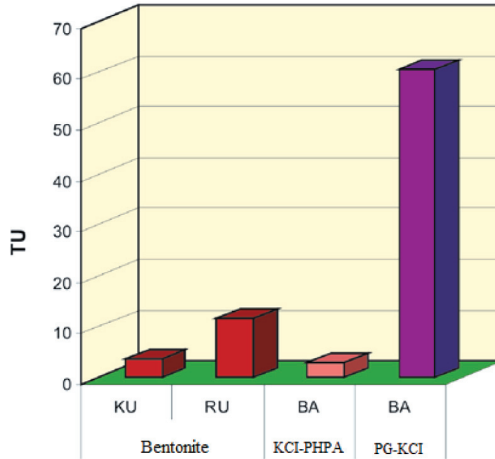


Fig. 4. Degree of toxicity of drilling muds

Source: Steliga and Uliasz (2012)

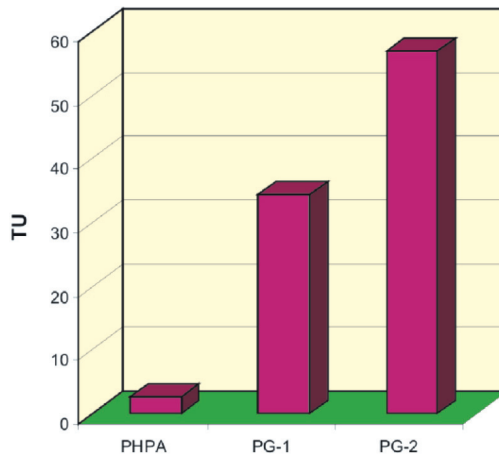


Fig. 5. Toxicity level of polymeric inhibitors

Source: Steliga and Uliasz (2012)

After the test, the highest toxicity characterized by a glycol-potassium mud, in the composition which uses PG-2 polymer inhibitor composition characterized by a high degree of toxicity TU = 56 (Uliasz et al. 2010).

The mud mixed with cuttings, depending on the soil and drilling technique, when we drill, it escapes from the hole to the initial or final excavation or through cracks in

the ground. It is exported by slurry tankers or specialized vehicles to remove such thick impurities. However, regardless of the export equipment, when we perform HDD controlled drilling, always some amounts of mud remain on the construction site near the excavation. The investor is often worried whether this is not toxic waste, whether he will not get a mandate for environmental pollution, whether it will not interfere with soil compaction (INSTDOM website, n.d.).

It should be borne in mind that the bentonite mud used for Horizontal Directional Drilling is not a binding material. After drilling work and leaving the mud in the hole, its aggregation will depend on the soil moisture content. It can take the form of a gel (with ground water pressure, the left mud can be washed away), or it can dry out (reducing its volume). Re-contact with water causes the dried bentonite to be liquefied again. Such filling of the hole can be treated as active ground, being aware that the above properties of bentonite mud do not guarantee a tight and permanently fill the space around the pipe (Szerszeń 2013).

4. Development and utilization of the drilling mud for HDD

During drilling works, liquid waste is inevitable, which is why all possible organizational and technological measures must be taken to properly manage or dispose of it (Macuda and Marchel 2011).

One way is to use the mud repeatedly, but then it must be stored. This type of drilling waste management increases the risk of ground and surface water and soil pollution. To minimize this risk, it is necessary to properly seal storage tanks and prevent liquid waste from entering the environment (Macuda and Marchel 2011).

Each mud after drilling the hole together with the extracted cuttings constitutes drilling waste, which is characterized by potential environmental damage, depending on the composition of the mud and the drilled rocks occurring in the hole profile.

Reduction of the amount and degree of harmfulness of waste is achieved by (Steliga and Uliasz 2012):

- effective drilling mud cleaning operations,
- economical scrubber management,
- proper waste storage.

To meet the requirements of rational waste management, drilling rigs are equipped in modern mud cleaning systems. A properly designed mud cleaning system helps to effectively control the following issues (Jamrozik 2009):

- costs of drilling waste disposal,
- costs for drilling mud preparation and processing,

- reduce expensive dilution,
- solid phase content,
- drilling progress,
- hydraulic parameters,
- technical condition of the hole.

To clean the mud from drill cutters there are used: vibrating sieves, hydrocyclones, desludges, desilters, and decanter centrifuges, degassers, flocculation stations. Thanks to them, it is possible to reduce the amount of spent drilling mud produced, and also the reuse of a significant proportion of the mud for a new mud or subsequent hole (Jamrozik 2009, Steliga and Uliasz 2012).

Drilling wastes (used muds) are handled through their processing in solidification and drainage processes.

Solidification (solidification) of rock cuttings transforms waste into a monolith, i.e. a form that is more stable. Therefore, the obtained material has increased physico-chemical stability and mechanical strength. The monolith is obtained as a result of the addition of binding materials in the form of Portland or multi-component cements, gypsum, lime and hydraulic pucalane binder to the waste, which lead to solidification by hydraulic binding of soluble compounds (e.g. chlorides) as well as heavy metals and petroleum substances. This process is most often carried out in the case of bentonite scrubbers, due to the obtained mechanical parameters and the degree of leaching of harmful substances from solidified material (Steliga and Uliasz 2012).

Dewatering of liquid drilling waste consists of chemical coagulation followed by filtration. The coagulation process is carried out by using appropriate mineral coagulants, mainly aluminum, because they are the most effective. However, by filtration it is possible to separate solids from liquids on the porous partition. The phase separation makes it possible to obtain material without liquid properties and has a dry matter content in the range of 40 to 60%. The filtrate in this form can be used for land reclamation.

The method of managing drilling waste is also landfilling, but disposal of waste in this way should be used as a last resort. In Poland, waste storage is carried out (Macuda and Marchel 2010):

- in Wronów, commune of Niechlów, voivodeship Lower Silesia,
- in Bukowiec, commune of Nowy Tomyśl, voivodeship Greater Poland (currently in reclamation),
- in Borzęcin (Żmigród commune, powiat of Trzebnicki, Dolnośląskie voivodship) using the depleted natural gas field for waste storage under a license granted to PGNiG S.A. by the Minister of the Environment.

Most of the resulting liquid waste can be recycled in municipal or industrial treatment plants (Macuda and Marchel 2011).

On the basis of the Regulation of the Minister of Environment of 27 September 2001 on the catalog of waste (*Rozporządzenie...* 2001), drilling muds and other drilling wastes are marked with subcode 05, and their individual types are listed in Table 1 (Gluzińska et al. 2014).

Table 1
Code of the drilling wastes

Code	Waste
01 05 05	drilling muds and drilling wastes containing oil
01 05 06	drilling muds and drilling wastes containing dangerous substances
01 05 07	drilling muds containing barite and other than those mentioned in 01 05 05 and 01 05 06
01 05 08	chloride-containing drilling muds

Source: Gluzińska et al. (2014)

5. Conclusion

HDD drilling is undoubtedly a minimally invasive technology for infrastructure and the environment. Considering the issue of environmental protection, the mud used for this type of drilling has a significant impact. The HDD drilling mud plays an important role in the whole process, but it carries a risk of environmental pollution. Each mud after drilling the hole, together with the removed cutting is drilling waste, and is often used many times. The HDD mud should be selected in the right way and then utilized to prevent any risk of environmental contamination.

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