Environmental impact of a drilling mud deposit

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ABSTRACT:

The paper deals with an investigation of a zinc-contamination near a drilling mud deposit in SW Hungary. The site was carefully explored using drillings, and a straightforward soil and groundwater sampling was completed. With various soil chemical tests it was proved that the source of contamination is not the mentioned deposit. During tests zinc-transport parameters were obtained from break-through curves and this values were used for simulation of natural attenuation of the zinc contamination.

1 INTRODUCTION

The stability of boreholes is assured using drilling muds. The mud can be recycled, but after several turns it becomes unusable and it is to be deposited. Several drilling mud deposits were established in Hungary in the last decades. There was a zinc contamination discovered nearby one of such deposits and effects of contamination on the environment were to be investigated.
The investigations were performed in order to determine the geological, hydrogeological conditions and environmental status of the area. The aim of investigation was to establish the groundwater flow and contaminant transport model of the system.
The paper presented deals with the investigations performed at a drilling mud deposit where zinc-contamination occurred.

2 DRILLING MUD DEPOSITS AND THEIR LEGISLATIVE STATUS IN HUNGARY

The drilling muds were classified as hazardous wastes in Hungary. Therefore this muds were deposited in mono-deposits constructed for this purposes. The general requirements against this facilities was minimum 100 000 m^3 capacity and 10 years duration of operation.
In 1996 the Hungarian legislation of hazardous waste disposal changed and therefore at all the drilling mud deposits an environmental impact assessment had to be completed.
The investigations showed an increased zinc concentration in some monitoring wells nearby and in order to determine the source of contamination and to evaluate the environmental risk represented by the existence of the deposits further investigations were prescribed by the authorities.

3 THE SITE OF INTEREST

The investigated drilling mud deposit was established in 1989, near Zalatárnok village for the storage of unusable drilling muds applied in SW Hungary.
A deposit is situated on the ridge of a small hill. The deposit consists of 18 storage cassettes constructed by excavation of the local soils. The depth of a cassette is 2,5-4,0 m, the size is 40-60 x 10-30 m (Figure 1.).
Considering the high adsorption capacity of the mud caused by high bentonite content and the low permeability of the mud no bottom and side lining system was planned to isolate the waste from its environment, only the local clayey formations were slightly compacted on the site. The

drainage of surface waters and collection of precipitation was also not solved. There is only drainage ditch was built in order to collect rains which conducts water to the small valley in W direction. All surface waters infiltrates on the slight slopes of the valley.
A GW monitoring system was established in 1990, the water quality monitoring is completed in every quarter.

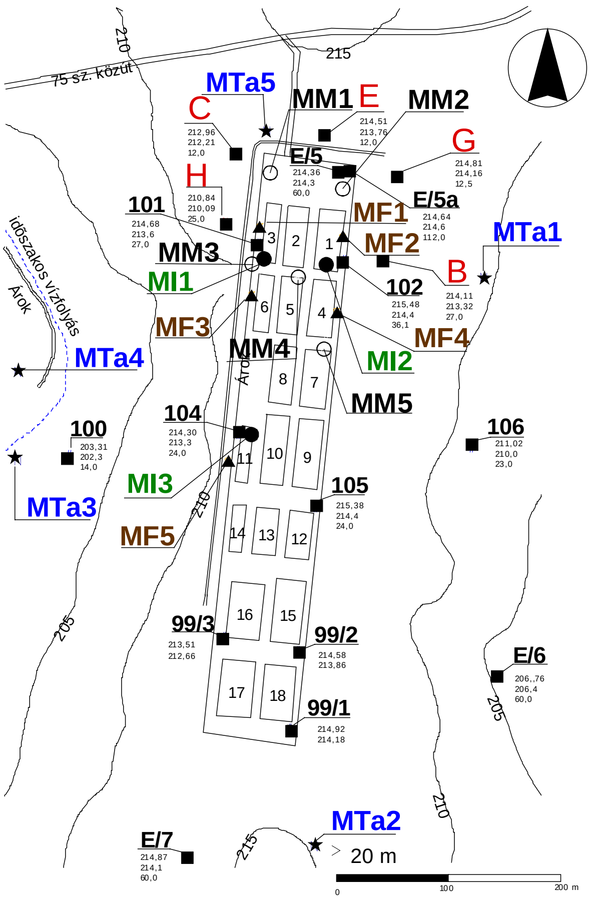


Figure 1: Scheme of the site

4 GEOLOGICAL AND HYDROGEOLOGICAL CONDITIONS

The top of the hill is built up from clayey, silty and sandy formations. The average thickness of clays is 7,4-11 m, of silts 0,5-2,8 m and of sands is 0,2 m. On the ridge of the hill a maximum 7,8 m thick, uniform clay cover was discovered with decreasing thickness in slope-direction. This clay has a medium and high plasticity (I_p=21-43%) and a low permeability. According to the laboratory measurements of undisturbed samples from the drillings performed the hydraulic conductivity of the clay is $K=3\div6\cdot10^{-9}$ m/s. The silts at the site are semipervious ($K=5\div20\cdot10^{-7}$ m/s).
At the bottom of the quarternary sediments Pannonian formations formed by clays, silts and sands occur. A representative cross section of the site is presented on Figure 2.
The groundwater-table at the valleys is near the surface meanwhile it is located in some 20-24 m depth below the ridge of the hill. There was a groundwater flow in direction E-SE in the first aquifer determined upon the data of monitoring wells nearby. This seepage is influenced by the morphology. The average hydraulic gradient in this Pannonian aquifer is $I=0,012\div0,023$.
In the second aquifer the regional GW flow to W-SW dominates. The scheeme of the GW flow regime is shown on Figure 3.

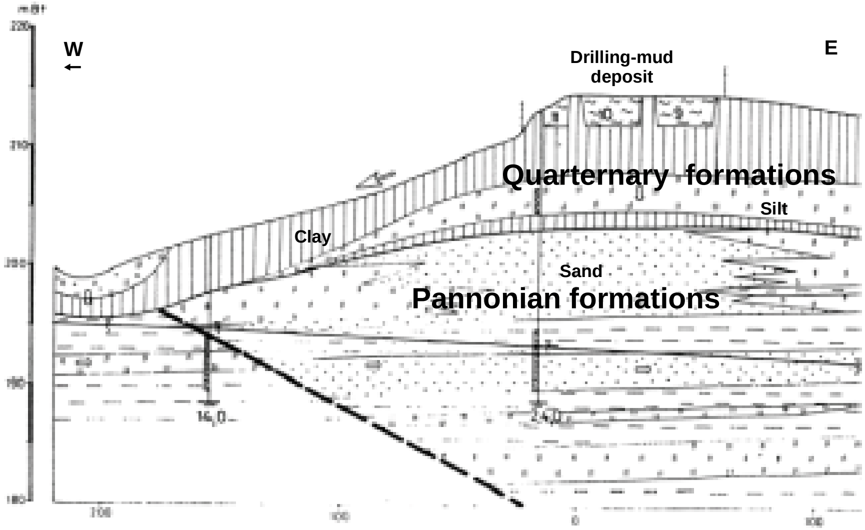


Figure 2: Representative geological cross section at the area

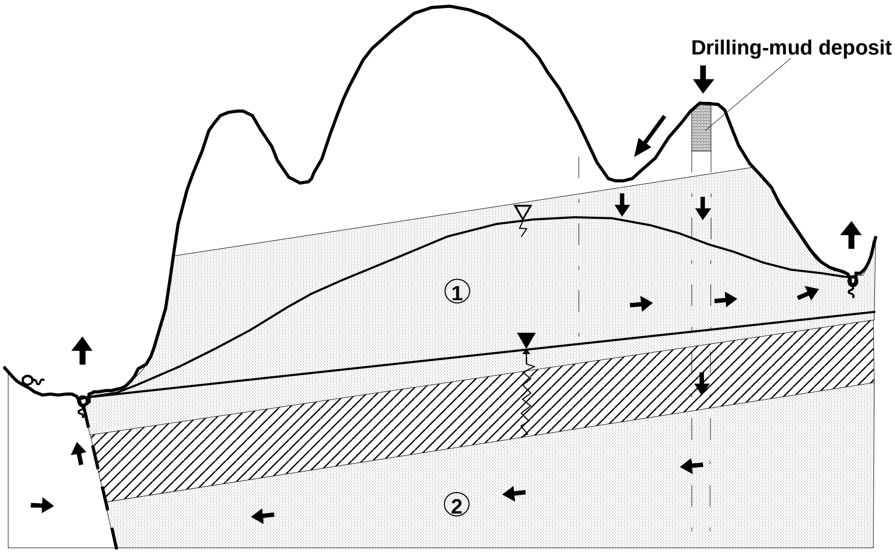


Figure 3: The GW flow regime at the site

5 EVALUATION OF SOIL ANALYSIS DATA

For investigation of zinc contamination several vertical and sloping boreholes were drilled (Figure 1.). The boreholes were sampled close to surface under it in every one meter. The pH and extractable zinc concentration of given samples were measured. The statistical distribution all of the measured data was Gaussian. The Gaussian distribution means there are no effects in the system that can locally change the original conditions (Figure 4.).
The sorption isotherms of the mud and the soil at the bottom of the cassette was also determined (Figure 5.) It was very interesting that the equilibrium zinc-concentrations for the mud were always lower that that for the bottomsoil of the deposit. This means that the direction of ion-transport is opposite that it was expected.
All the zinc concentration and pH data significantly and slightly increased in function of depth. At the bottom of the mud cassettes there was only a continuous change in the measured values. All the facts show that there is no direct contaminating effect of drilling-mud deposits.

The phenomena, mentioned above was also detected in the monitoring-wells, but in these cases the zinc-concentration increased only in the upper 9m of the soil sequence. At 9 m depth the concentration jumps to a constant higher value.

Although this high contamination not originated from the investigated ponds, to estimate the environmental risk, the parameters of zinc-transport were determined by laboratory experiments.

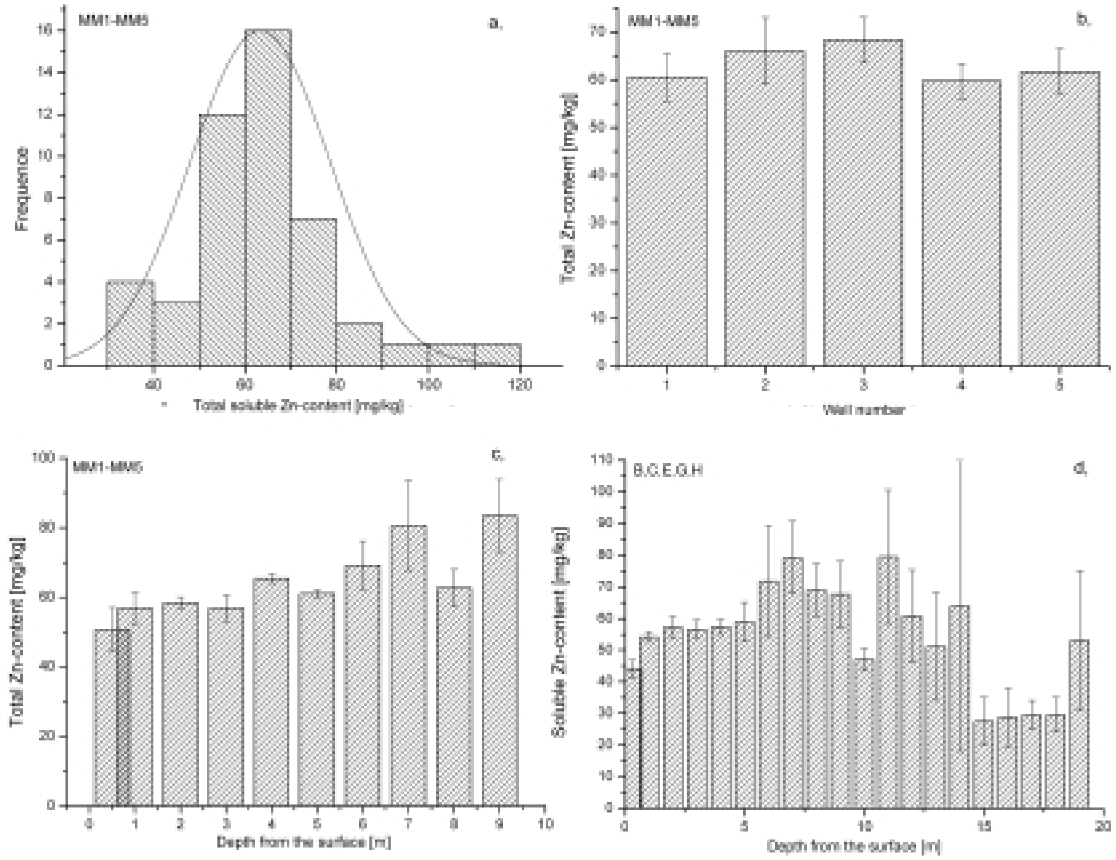


Figure 4: Results of statistical investigation of Zinc concentrations of soil samples

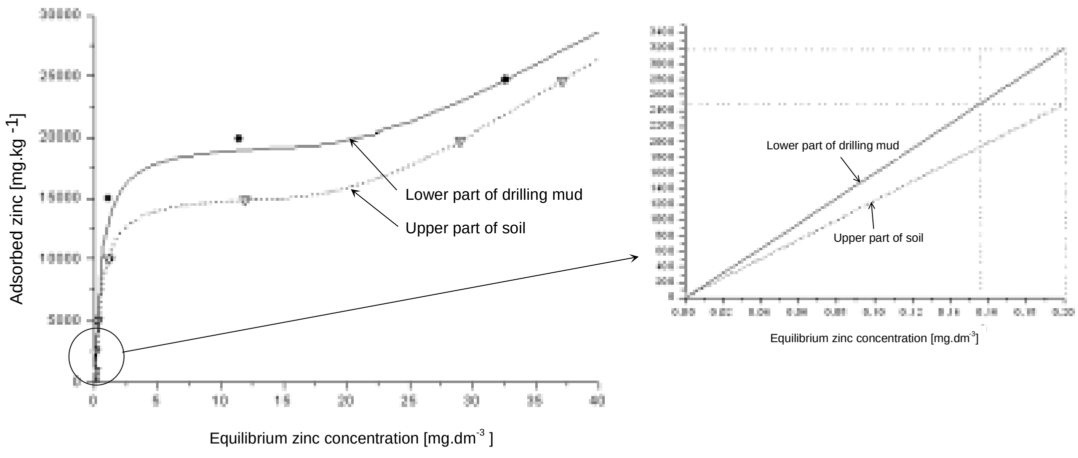


Figure 5. Adsorption isotherms of mud and soil

6 LABORATORY DETERMINATION OF ZINC-TRANSPORT PARAMETERS

The determination of transport parameters was performed in a flexible-wall permeameter using undisturbed soil samples from the drillings. The equipment is capable to determine the hydraulic permeability of the 2-3 cm thick sample during the experiment but it was also useful to calculate the transport-parameters and Zinc retention capacity. Both below and above the sample a filter was installed to avoid the grain outwash from the sample. The sidewall of the sample was covered with a membrane and it was pressed to the sample using 0.1 atm higher pressure than the pressure of the test fluid. During the test distilled water was used until the full saturation of the sample and until reaching the steady-state migration through the sample, at I=30 hydraulic gradient. From the water volume migrated through the sample the Hydraulic conductivity was calculated using the constant head principle. After that phase the test fluid was changed to another fluid with 20 ppm lithium-, and 1500 ppm zinc-ion content. The effluent solution was then collected and analysed. Both the lithium and the zinc-concentration were measured and the break-through curves were determined. The lithium–ions were used as control tracer, since the adsorption of this ions in soils is negligible in comparison to the zinc-ions.

The evaluation of the results was performed using the curve fitting method. The analytical solution of the 1D transport equation for the investigated case can be written in the following form:

$$c = c_0 \cdot \left[\frac{1}{2} \cdot \operatorname{erfc}\left(\frac{R \cdot z - v \cdot t}{\sqrt{D \cdot R \cdot t}} \right) + \frac{1}{2} e^{\frac{v \cdot z}{D}} \cdot \operatorname{erfc}\left(\frac{R \cdot z + v \cdot t}{\sqrt{D \cdot R \cdot t}} \right) \right] \tag{1}$$

where c is the concentration, c_0 is the concentration of the influent solution, R is the retardation factor, D is the effective dispersion-coefficient, v is the seepage-velocity, t is the time and z is the distance along the axis.

For the curve fitting the following transformations were used:

$$t = \frac{x}{v} \text{ and } v \cdot t = x\,, \tag{2}$$

where x is the volume of effluent fluid.

The transport equation after transformation:

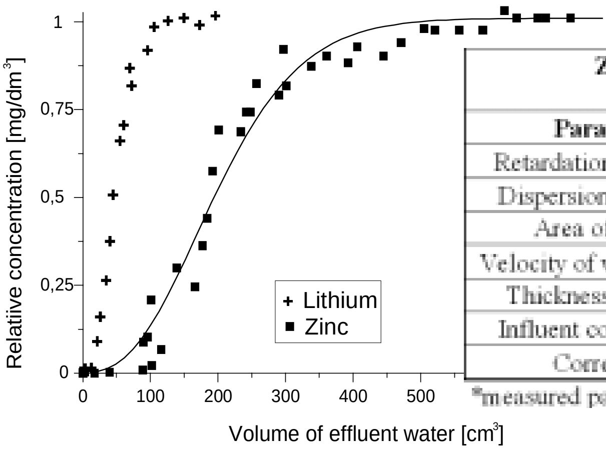
$$c = \frac{c_0}{2} \cdot \left\{ \left[1 - \operatorname{erf}\left(\frac{R \cdot z - \frac{x}{A}}{\sqrt{D \cdot R \cdot \frac{x}{v}}} \right) \right] + e^{\frac{v \cdot z}{A \cdot D}} \cdot \left[1 - \operatorname{erf}\left(\frac{R \cdot z + \frac{x}{A}}{\sqrt{D \cdot R \cdot \frac{x}{v}}} \right) \right] \right\} \tag{3}$$

Using the curve fitting both the dispersion –coefficient, both the retardation factor was calculated (Figure 6.)

7 CONTAMINANT TRANSPORT MODELING

Based on hydrogeological investigations performed, chemical analysis of soil samples and laboratory determination of zinc transport parameters a contaminant transport model of the study area was built up. The aim of the modeling was to estimate the environmental risk of the potential pollution on the waterworks in the surroundings of the site.

The model based on the GW flow regime previously discussed. We simulated the zinc transport with initial concentration distribution measured in the monitoring wells. Using the model the concentration distributions vs. time were calculated (Figure 7.). It was proven that the zinc contamination discovered has negligible effect on the well of the water-works because of their distance and of the semipervious layers between them. The investigation lead to the conclusion that the monitoring network is to be refined and a monitored natural attenuation as remedial activity was suggested.



Zinc-transport parameters obtained with curve fitting method				
Parameter	Unit	Sign	Value	Error
Retardation coefficient	-	R	11.85	0.36
Dispersion coefficient	$cm^2.s^{-1}$	D^*	$1.46.10^{-6}$	$2.12.10^{-7}$
Area of sample	cm^2	A	35.77	-*
Velocity of water seepage	$cm^3.s^{-1}$	v	$8.74.10^{-5}$	-*
Thickness of sample	cm	z	1.01	-*
Influent concentration	$\mu g.cm^{-3}$	c_0	882	27.1
Correlation	-	R^2	0.989	-

*measured parameter.

Figure 6: Break-through curves measured and fitted

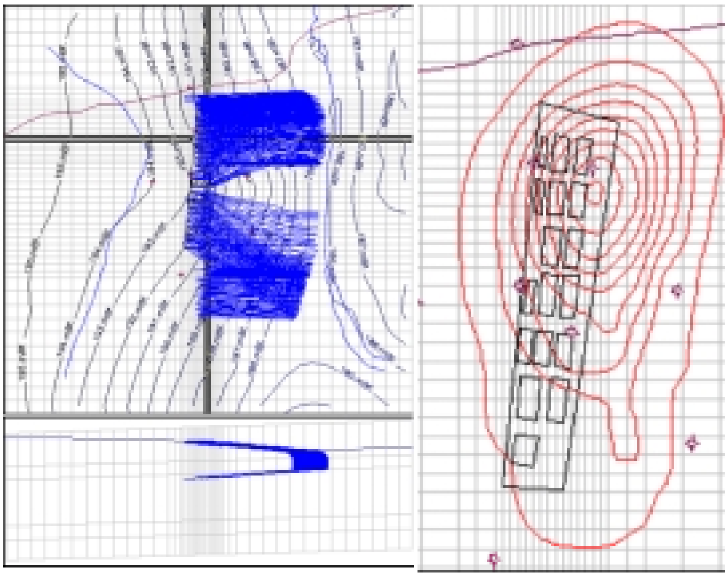


Figure 7. Pathlines starting from the deposit and concentration isochrones during natural attenuation

8 CONCLUSION

The investigation of the site was completed using drillings, soil and groundwater sampling, laboratory investigations, special chemical analyses. The experiments and test performed proved that the zinc, which was found in the monitoring well surely not originated from the drilling mud deposit. The hydraulic conductivity and break-through tests performed in flexible-wall permeameters were very useful and gave good, reproducible results. The method to obtain transport parameters for heavy metals and other contaminants will be continued in the future.
Since the measured concentrations slightly exceeded the Hungarian limit values, a contaminant transport model was built to simulate the natural attenuation of the zinc contamination. A suggestion was given to refine the observation network to control the attenuation of the zinc contamination.