The optimal strategy of cleaning of fucoid sandstone

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Introduction

Uranium ore was exploited in the Stráž deposit of north-bohemian cretaceous sediments. There was also used in-situ leaching. Now there is running an extensive remediation process of rock environment. In Cenomanian aquifer there are 4.5 millions tons of dissolved substances. Two strata form the aquifer: friable and fucoid sandstones stratum. Lower friable sandstone stratum is 15 - 25 m thick and it is well permeable. Fucoid sandstone roof is about 40 metres. It is not wholly homogenous strata. The sub layer permeability ranges from centimetres to decimetres per day and it is almost twice lower then friable sandstone.

The contamination's scale of the fucoid sandstone is very changeable. In some places the contamination permeates the whole strata in the concentration reaching 50 g/l TDS. In general, the concentration is not so strong and declines in upper sub layers. Sometimes the contamination doesn't touch the top of the strata. The

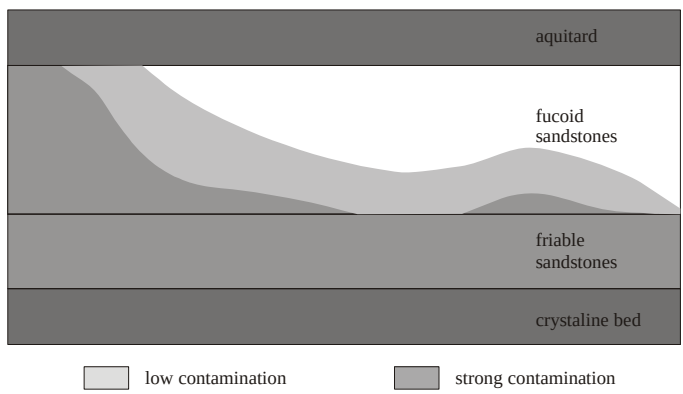

Fig.1. Distribution of contamination in Cenomanian aquifer.

amount of the contamination of fucoid sandstone is about 35 %. The situation of contamination in the Cenomanian aquifer is at Fig. 1.

All computer models result in a necessity of at least partial cleaning of the fucoid sandstone strata. At this time the cleaning is rating to well permeable friable sandstone places of high contamination. At present time there are used the original exploitation pumping wells which were opened at the cenomanian base. At this method of pumping solids off, the contamination's scale in fucoid sandstone will lower only a little at the time of achievement required rank.

The purpose of this work is to find the optimal and effective method of cleaning the worse permeable layers. According to the results of this work, there are chosen the places of fucoid sandstone needing to be clean and which method will be used.

Methodology

To reach the effective cleaning of the fucoid sandstone there is three possibilities:

- Drawing solutions from the layers under the top of the strata
- Forcing out the contamination by injection the water or slightly alkaline lotion into these layers accordingly with drawing from the permeable friable sandstone sub base
- And to combine both preceding steps - to inject to the fucoid sandstone and to draw from this one

There is scheme of these processes at the Fig. 2a,b,c. There is demonstrated the flow on the left of figure. On the right there is the allocation of residual contamination that characterize proceeding of cleaning after the time.

Several modelling tools were developed to find the effective method of remediation. They can monitor the amount of the withdrawn solids and the evaluation of situation in the underground. Technological and economical extensions serve for comparison of particular cleaning scenarios.

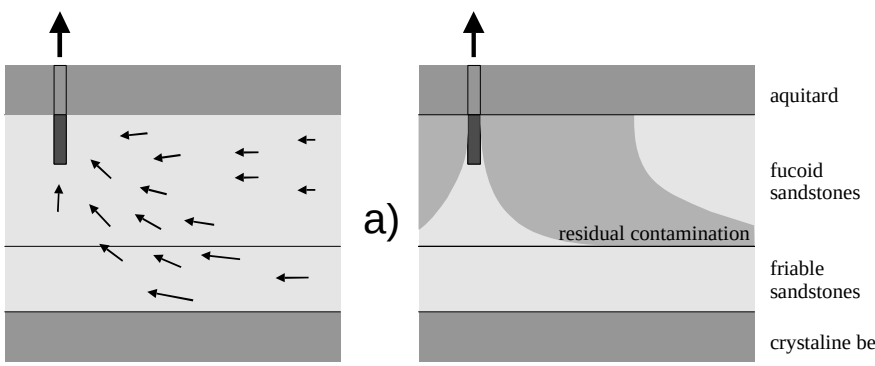

Fig. 2a. Drawing solutions from the layers under the top of the strata.

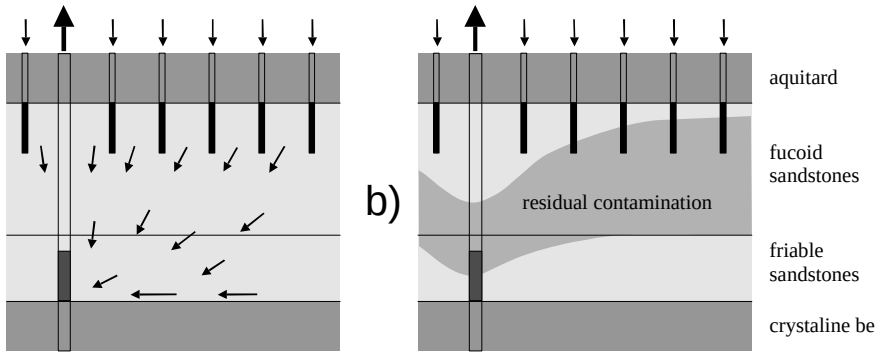

Fig. 2b. Forcing out the contamination by injection the water or slightly alkaline lotion into these layers accordingly with drawing from the permeable friable sandstone sub base.

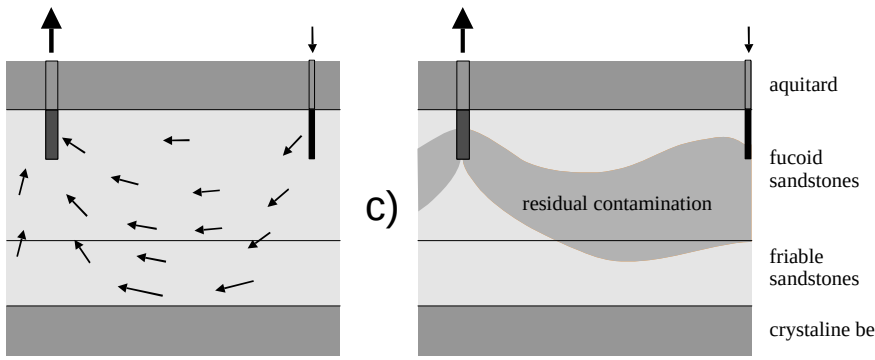

Fig. 2c. Injection to the fucoid sandstone and drawing from this one.

Ranking of the technological effect

The first step in our solution is the simulation of underground processes (flow and transport) in dependence on well pattern configuration. The amount of removed solids out from the fucoid sandstone stratum expresses the technological effect of remediation process. The pattern of well spacing agrees with actual situation in Straz deposit. The capacity of pumping wells is 300 l/min default. This well is possible to clean various measure of deposit area. There can be used the current wells to pump the contamination solids out from lower friable sandstone stratum. For direct pumping from fucoid sandstone stratum there is necessary to drill new wells.

At places with the highest scale of contamination there are used the square modules 28x28 m of well nets. Those wells have small boring diameter and they

can't be used for pumping the solids out but for injection to fucoid sandstone stratum.

DIAMO cooperated with Technical University in Liberec to develop the mix-hybrid model of the finite element method. This model was used for the computer simulation of remediation. In the first stage of project there were simulated variant calculations on the schematic model mesh. The model mesh was divided into 18 layers with 3 m thickness. The physical parameters of each layer are shown at the Fig. 3.

In the first, second and third column (k_x, k_y, k_z) there are the coefficients of hydraulic conductivity in direction of particular axis. The coefficients are in m/day. Then there follow dates about active (n_a) and total porosity (n_Σ). The parameter α indicates the rate exchange of solutions between active and inactive pores. This time in days is needed to reduce the concentration differences scale down to the half.

There was the square mesh at the ground plan. This mesh covers a quarter of the area where is one pumping well. The module of inner dividing came up to the mesh of present used wells that is 28 x 28 meters.

		parameter					
	model layer	k_x	k_y	k_z	n_a	n_Σ	α
fucoid sandstone	F13	0.6	0.6	0.3	0.08	0.32	180
	F12						
	F11						
	F10	0.3	0.3	0.15	0.08	0.32	180
	F9						
	F8						
	F7	0.5	0.5	0.25	0.08	0.32	180
	F6						
	F5						
	F4	0.05	0.05	0.02	0.04	0.32	720
	F3						
	F2	0.5	0.5	0.25	0.08	0.32	180
	F1						
friable sandstone	R5	4	4	2	0.1	0.25	120
	R4						
	R3						
	R2	2	2	1	0.1	0.25	120
	R1						

Fig. 3. The physical parameters of idealized rock environment of Cenomanian collector.

The Fig. 2a shows the pumping from fucoid sandstone stratum. In case of pumping from underground friable sandstone stratum, (Fig. 2b) the injecting wells were staggered with various densities (4 - 15 wells/ha) at the whole area. In case of pumping from fucoid sandstone stratum, (Fig. 2c), they were staggered around periphery of area. The extent of area belongs to one pumping well were changed in several variant (from 3 - 30 ha). As well the started contamination's range were various to correspond to the mostly occurred types at the Stráž deposit.

At the Fig. 4, there is comparison of technological effect of different cleaning methods. The concentration curves of contamination in pumped solutions are plotted at the Fig. 4a, residual contamination proceeding is at the Fig. 4b.

The strongly contaminated area, which is cleaning by one pumping well, is 8 ha large. Only the pumping of solids from fucoid sandstone stratum leads to the fastest cleaning. With area enlargement it is more effectively both to pump out from fucoid sandstone stratum and to inject to this one.

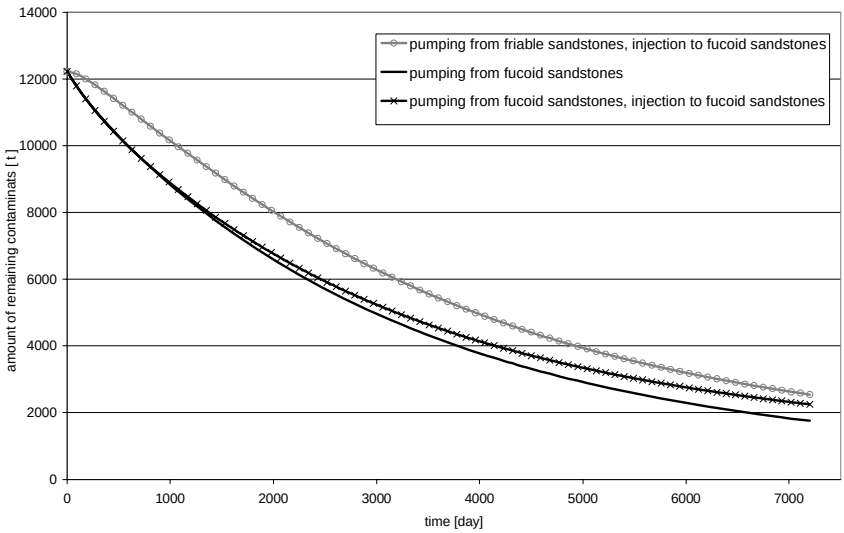

Fig. 4a. The comparing of technological effect of different cleaning methods - concentration curves of contamination in pumped solutions.

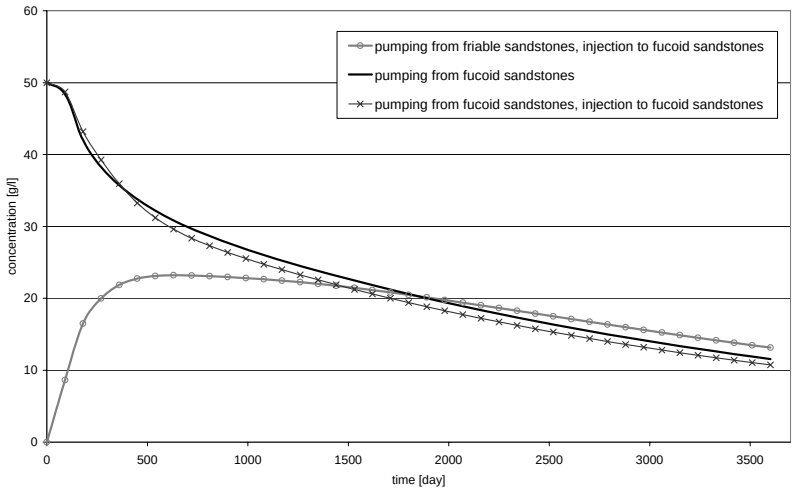

Fig. 4b. The comparing of technological effect of different cleaning methods - curves of concentration of residual contamination.

The optimizing problem

The efficiency of variant cleaning method depends on started contamination's range at a concrete place of Stráž deposit and on required target of residual contamination. The residual contamination at the monitored place can differ from required target to whole Cenomanian aquifer. The efficiency can be evaluated by economic criteria.

At first, it is necessary to build the cost model. The costs are divided into the fix costs and variable costs. The fix costs are considered as costs for preparing the particular cleaning site (drilling, pipe lines, etc.). The variable costs represent the volumes of injected and abstracted solutions (the unit costs were calculated per 1 m^3), salaries, maintenance and monitoring (unit costs were calculated per 1 ha per year).

The target of the cleaning is to remove a certain amount of contaminants so that the needed level of remaining contamination is achieved. So, the costs for removing of 1 kg of contaminants were chosen as the decision criterion. At the Fig. 5 there are shown the dependences of the total and unit costs on the amount of removed contaminants.

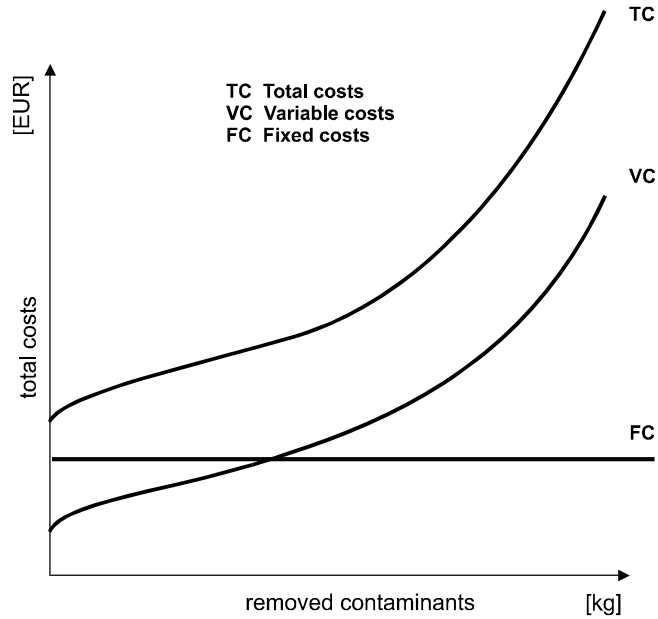

Fig. 5a. The dependence of total costs on amount of contaminants removed.

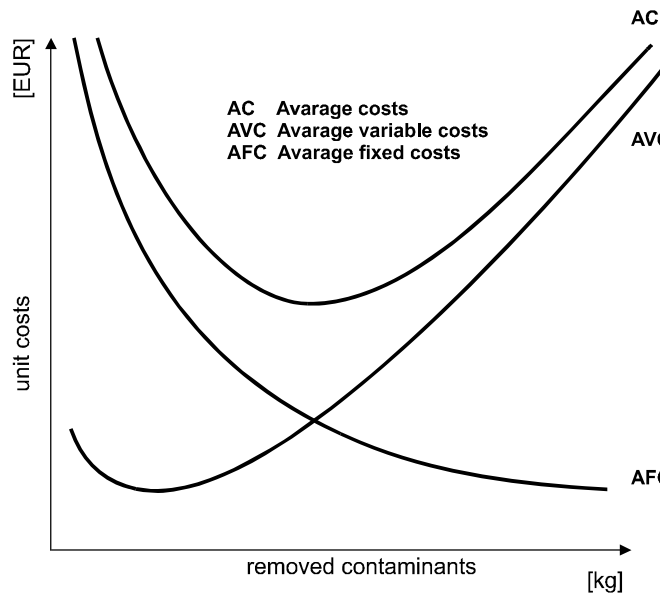

Fig. 5b. The dependence of unit costs on amount of contaminants removed.

To find out the effective method of cleaning the modelling tool were developed. The models enable us to observe the amount of contaminants removed and to evaluate the situation in the underground. The technological and economical models serve for comparison of efficiency of individual cleaning scenarios. The obtained results we use for decision making in the whole remediation process.

Obtained results

The contaminated sites up to ca 30 ha can be effectively cleaned by one abstraction well. If the area is up to 12 ha, the most efficient method of cleaning is to use single well opened under the ceiling of the fucoid sandstone strata, see the Fig. 2a. Such method is more efficient than displacing of contamination (see Fig. 6). For areas between 12 and 30 ha is good to complete the single abstraction well by injection of water into the strata. It causes the displacing of the contamination.

The large continuously contaminated areas they are necessary to clean by contamination displacement by area injecting (Fig. 2b). The wells should be opened in friable sandstone strata. The density of the abstracting well pattern is more considerable than the density of the injecting well pattern. In the case of strong contamination, (see Fig. 8), it is suitable to use quite dense well pattern (224 x 224 m).

In the case of weak contamination, (see Fig. 8), it is suitable to use quite sparse well pattern (336 x 336 m), when demands on the target level of cleaning are not so strong. On the other hand, when demands on the target level of cleaning are too strong, it is suitable to use quite dense well pattern (224 x 224 m).

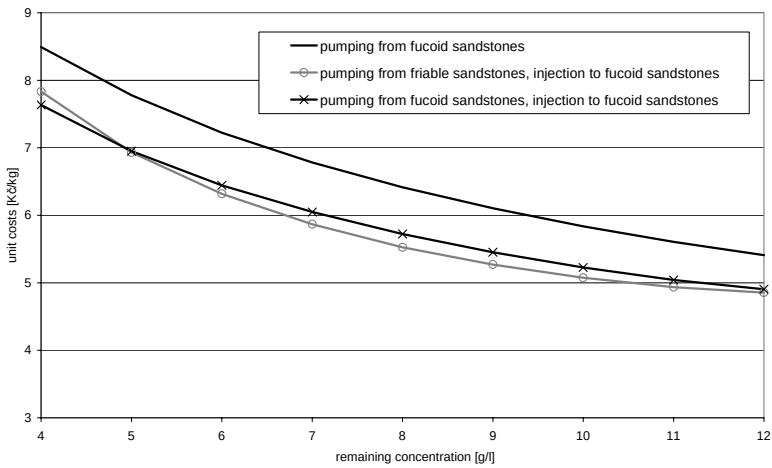

Fig. 6. The efficiency of cleaning methods – contaminated area – 8 ha.

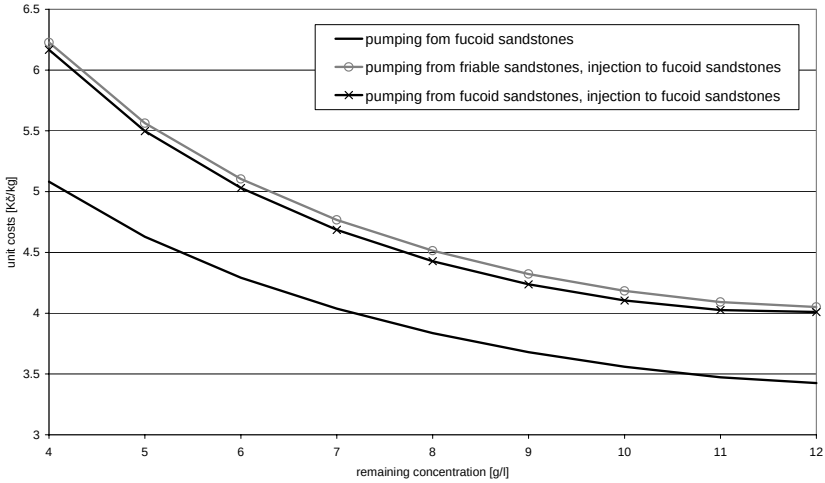

Fig.7. The efficiency of cleaning methods – contaminated area – 16 ha.

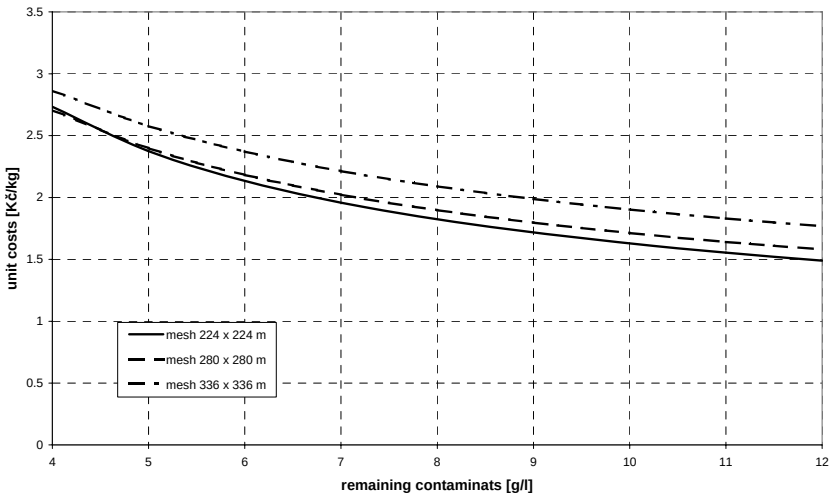

Fig. 8. **T**he efficiency of density of well pattern – strong continuous contamination.

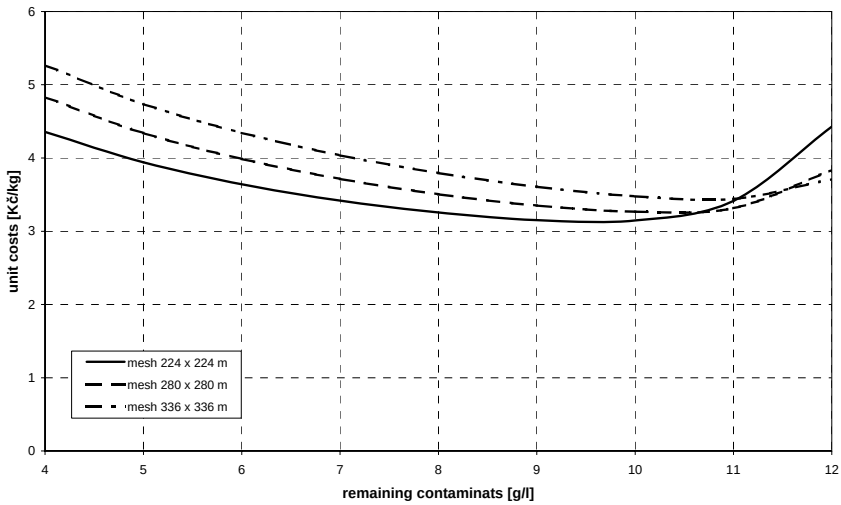

Fig. 9. The efficiency of density of well pattern – weak continuous contamination.

Conclusion

The removing of contamination from low permeable geological layers neighbouring high permeable layers is specific task in the frame of remediation of rock environment in the former uranium deposit Stráž. For the solution of the task the modelling system was developed. Using the system, we can evaluate technologic and economic effect of various cleaning approaches. The calculation results indicated the main principles of effective cleaning strategies. The system developed is suitable for planning and decision making during the remediation process. It is also suitable for specification of methods of cleaning of contaminated areas with the view to physical, geological, geochemical and other parameters.

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