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Experience with an in-situ ground cementing using sodium aluminate water glass gel

Expériences de cimentation in-situ par du gel de verre soluble à base d'aluminate de sodium

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ABSTRACT: During the construction of a new thermal waste treatment plant, the MVB, from 1991 to 1994, especially the foundation pits for the refuse bunker and the rain retention reservoir, it was necessary to inject sodium aluminate waterglass gel into the foundation soil where it solidifies to form a one metre thick hydrogel with a very high water content and low solidity.

To find out which kind of parameters may disturb the ground water quality after the injection a monitoring program was conducted and the collected data during the building area were analysed. Attention was given to the concentration of sodium and aluminium in the ground water. From the results it can be concluded that there will be no environmentally relevant influence. Further monitoring programs during and after a water glass gel injection should be restricted to the analysis of important reference parameters of the ground water before the injection and the quality of the water used for the injection.

SOMMAIRE: La société MVB avait été dans l'obligation, pendant la construction d'une nouvelle installation aux grandes dimensions pour le traitement des ordures de 1991 à 1994, et notamment pendant le creusement de la fosse pour les fondations des réservoirs de refoulement et de rétention des eaux de pluie, d'injecter du verre soluble sous forme de gel et à base d'aluminate de sodium dans les cavités du sol des fondations, afin de les solidifier pour obtenir une couche d'hydrogel d'une épaisseur d'un mètre avec une teneur en eau extrêmement élevée et une basse solidité.

Suite à ceci et afin de déterminer les paramètres susceptibles de perturber la qualité des eaux souterraines après l'injection du gel, on a mis un programme de monitoring en place et on a analysé les données recueillies pendant les constructions au niveau du sous-sol. Les données relatives à la concentration de sodium et d'aluminium dans les eaux souterraines étaient particulièrement intéressantes dans ce contexte. Les résultats des analyses permettent de constater que ce procédé n'a aucune influence néfaste sur l'environnement. Les programmes de surveillance ultérieurs, pendant et après une injection de gel de verre soluble, pourront effectivement se limiter à un contrôle des paramètres déterminants d'analyse des eaux souterraines avant l'injection et à la qualité de l'eau utilisée.

1 Introduction

Water glass is the term used to describe glass-like alkali silicates and their strongly basic-reacting, aqueous solutions. In terms of use in building industry, the important ones are sodium water glass (from Na_2SiO_3 and $\text{Na}_2\text{Si}_2\text{O}_5$) and potassium water glass (from K_2SiO_3 and $\text{K}_2\text{Si}_2\text{O}_5$) which are sold commercially in the form of solid glass.

In order to produce alumina silicate gels for use in building work, dilute aqueous solutions of sodium silicate and sodium aluminate are injected into the foundation soil, where they solidify to form a hydrogel with a very high water content and low solidity.

Injections based on sodium aluminate water glass gels reduce the water-permeability of porous ground, whereby the coefficient of permeability k is reduced by several decimal factors. Besides many other fields of application, these are therefore used as an auxiliary measure in inner-city building projects to seal off foundation pits below the ground water level against truding water. The layer allows the foundation pit to be kept dry without making it necessary to lower the ground water level.

Since, on the one hand this technology has come into increasingly wide use over the 20 years of its existence and, on the other hand, a disadvantageous alteration of the ground water quality must be expected when introducing large volumes of chemicals into the ground water aquifer, an increasing interest exists in gaining knowledge of the possible effects on the ground water of injections of sodium aluminate water glass in porous ground.

2 Application in the refuse bunker and rain-retention reservoir at the MVB

In the course of the construction of a new thermal waste treatment plant for residual residential waste at Muellerverwertung Borsigstrasse (MVB) carried out between September 1991 and March 1994 in Hamburg, the foundation pits for the refuse bunker and the rain-retention reservoir were constructed in the form of sheet-piling foundation pits sealed off with an injected foundation level around one metre thick.

2.1 Description of the process

The injected foundation level was created from the preliminary excavation level around 3 m below the existing site level and was based on the so-called monosol process with sodium aluminate water glass gel (16 vol.% waterglass, 82.4 vol.% water, 1.6 vol.% sodium aluminate). One injection was carried out for the creation of each 1.5 m² of injected foundation layer. To do this a bore was made into the middle of the injected foundation layer by means of the hydraulic packing method using a supporting fluid (bentonite, cement suspension) into which the injection lance was inserted. The sealing material with a total quantity for both foundation pits of approx. 1,000 m³ (water glass content around 157 m³) was then injected.

After completion of the injected foundation layer around 4 - 5 l/sec. of surface water and seepage water per 1,000 m² collected in the two foundation pits with a total area of around 2,000 m² at a water pressure on the injected foundation layer of around 1 bar. This water was pumped off, the quality monitored and fed into the public drainage system for the duration of the construction period.

2.2 Approval and monitoring

The construction and operation of the MVB was approved in accordance with art. 7 (1) of the Waste Act (AbfG). The earlier commencement of building work, including the construction

of the rain-retention reservoir and the refuse bunker, was approved through a permit in accordance with art. 7a AbfG and a water conservation permit in accordance with art. 3 and 7 of the Water Conservation Act (WHG). The extensive conditions imposed with respect to the performance of building work and preparatory measures required, among other things, that an expert was called in to monitor and document possible effects of the sodium aluminate water glass injection on the main ground water aquifer.

The objective of the above monitoring program was to enable the use of water glass for further building projects to be approved on the basis of verifiable findings ruling out negative consequences.

In order to monitor the effects of the injection work on the ground water, six ground water measuring points (GWMP) were used to observe water levels and to take samples in order to implement an extensive programme of analyses. In addition to numerous parameters for checking the quality of the ground water the analyses included parameters relevant to the injection medium such as silicon, sodium and aluminium. The scope of parameters and the frequency of testing are shown in the following table:

Parameters	2 x week ly during injection work	before start and monthly for 6 months following completion of injection work, plus yearly analyses until 1992	Analyses to be carried out annually (reduced scope from December, 1992)
pH value, conductivity, temperature, overall hardness	x	x	x
CaCO ₃ hardness, Ca hardness, Mg hardness		x	
Fe, Mn, Na, K, BO ₃ , Si, Al, As, Cr, Zn, Ni, NH ₄ , NO ₃ , SO ₄ , KMnO ₄	x	x	x
Co		x	
Cd, CN, Hg, Cu, Pb, Cl	x	x	
Mo, V, Tl, F, NO ₂		x	
PAK/TVO		x	x
BTXE	x	x	x

Further ground water examinations are carried out at yearly intervals until the measuring program is stopped.

3 Examination results

During the test period November 1991 to October 1993 a total of around 260 water samples were chemically analysed by an officially-recognised test centre.

3.1 Physical parameters

Regarding the pH value of the ground water (average pH value 7), an increase in the pH value was to have been expected due to the alkaline character of the water glass (pH 10). The expected increase in the pH value of the ground water could not be detected.

The examined ground water was hard (hardness levels in accordance with Klut-Olszewski). The conductivity was within the natural range (on average, 1,200 to 1,400 µS/cm). The

temperatures ranged from around 10°C to around 13°C. No noticeable change in the physical parameters of the ground water through the sodium aluminate water glass gel was detected.

3.2 Changes in concentrations of parameters relevant to the injection

No changes in the silicon concentration (normally between 10 and 14 mg/l) which could be clearly attributed to the injection medium, e.g. in the form of a continuous increase in concentration, were detected.

The concentrations of sodium varied at an increased level (average values between 80 and 140 mg/l). Due to the high sodium concentration analysed before the start of injection this is not attributed to the sodium aluminate water glass gel. The recorded level of concentrations of sodium and also the high concentrations of potassium and chloride are probably geogenic in origin.

The concentration of aluminium, measured in the ground water area between the rain-retention reservoir and the refuse bunker before the start of injection at a maximum of 0.05 mg/l (in one GWMP), increased during the period of injection work, in some cases up to a peak value of 5.9 mg/l. No further noticeable increasing concentrations were detected after the completion of injection work. An influence on the ground water by the injection medium in the form of a short-term increase in concentrations of aluminium is to be assumed. In view of the very low overall aluminium content the recorded rise in the concentrations is not significant in terms of the ground water quality.

3.3 Other parameters

Most of the analysed substances displayed non-uniform changes in their concentrations at the different measuring points over the measuring period. The measured increased concentrations of toxic substances, changing from one area to another during the period of injection work, indicated changing ground water flow circumstances. This is supported by random sample measurements, on the basis of which no clear direction of ground water flow could be determined.

The organic toxic substances, borate, nitrate, high ammonium-, sulphate-, iron- and in some cases arsenic contents measured at some measurement points in addition to the increased heavy metal contents as well as a recorded Na/K ratio of less than 5, suggest anthropogenic influences from several different sources.

Generally, it should be said that a series of substances (Fe, Mn, K, As, NH₄, Cl, Mo, Tl, PAK) displayed detectable concentrations prior to the commencement of injection work due to a basic contamination of the primary groundwater aquifer. Since comparable or lower concentrations were measured after the start of injection work an increase in the concentrations of the above substances resulting from the injection of sodium aluminate water glass gel could not be proved.

4 Conclusion

According to the results obtained up to date, no environmentally relevant influence on the concentrations of substances in the ground water through the sodium aluminate water glass gel medium is recognizable. The non-uniform changes in concentrations over this period result from changing directions of ground water flow and the varying prior geogenic or anthropogenic loads. The short-term increase in concentrations of aluminium is not of significance to the ground water quality due to the low overall concentration. The consistently high concentrations of sodium, potassium and, especially, chloride may cover up possible light effects of the sodium aluminate water glass gel injection.

Future monitoring in the course of new injection measures should be carried out with a significantly reduced scope of

parameters in order to save costs. The inclusion of parameters not relevant to the injection should be restricted to the important reference parameters for the respective ground water conditions. To increase the reliability of the reference measurement and to extend knowledge of the background levels referring to the parameters to be monitored it is essential that a picture of the prior levels by means of several examinations of the relevant parameters - carried out at intervals - is obtained before injection work is commenced. Furthermore the water used in the injection mixture should also be included analytically in the monitoring in future in order to assess any possible influence on the ground water through an injection of water glass.