Exploration of Mineral Water in Coal Mining Areas

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It is well known that in most areas of Central Europe it is not difficult to find water - usually at shallow depths - and to recover and use this water.

What is much more difficult, however, is to find water sources that offer both sufficient in quantity and quality. Far too often, there are sources that offer abundant quantities but of poor quality or vice versa, i.e. high quality water but insufficient volumes.

In the former case where water quality is not adequate - which is more often than not due to anthropogenic factors and only very rarely a result of geogenic effects - the application of treatment techniques can help to turn such water into potable water that is suitable for human consumption.

High-quality properly mineralised groundwater - as a commodity - can be bottled and offered to the consumer untreated as »natural mineral water«. As regards the profitability of the bottling company, once again the question about the quantity of mineral water available is of considerable importance.

In the case of simple drinking water, the legislator has laid down quality standards for the safety of water for human consumption.

In general, these standards can be maintained by applying appropriate treatment techniques. Nevertheless, there may be conditions under which such water is no longer safe for human consumption. In such cases, public water works have to stop operating, since they are no longer capable of treating water contamination or because there is a risk that the groundwater might be severely contaminated.

In fact, such a situation arose in early 1987 when the water works located in the vicinity of the banks of the river Rhine had to be shut down because of toxic substances spilled into the river in Basle which were moving downstream.

Generally speaking, the treatment processes applied are getting more sophisticated from year to year and hence more expensive. Pollution of the environment does not spare groundwater, on the contrary, at times, underground water resources turn into condensates of air and water contamination.

The standards applying to **mineral water** that is awarded the quality mark »natural« have been set by nature. The legislator merely ensures, by means of laws and regulations, that this water - which then is a valuable commodity - is in fact untreated, i.e. »natural« and that it is offered to the consumer in that condition.

Such groundwater must therefore comply not only with strict criteria in terms of its safety for human consumption, but it is also supposed to promote human health, enhance the individual's well-being, and offer natural purity, i.e. it should be free of any harmful substances whatsoever.

II.

In the past, the criteria set to assess whether a given mineralised groundwater qualified as »natural mineral water« varied widely from one country to the other. As a case in point, mention can be made of the different views prevailing in France and West Germany as to what type of mineral water was more conducive to promoting human health and what water qualified as »mineral water« at all.

In West Germany, it was held that mineralised groundwater should contain at least 1000 mg/l of total dissolved solids (TDS) in order to deserve being called »mineral water«, while the view held by Germany's French and Belgian neighbours was diametrically opposed. They maintained that only very low-TDS groundwater - in some instances, less than 50 mg/l - could claim to promote human health. This view is shared in many other parts of the world.

III.

In order to harmonise these widely varying views and assessment criteria, and in order to be able to offer consumers all across the European Community (EEC) a commodity that is produced and bottled in accordance with the same standards, a Mineral and Table Waters Regulation has been adopted by the European Parliament after a rather long period of preparation and has since been transformed into national law.

This regulation became legally effective in the Federal Republic of Germany in 1984 by a decision of the Bundesrat, the upper chamber of the German parliament, and it was put into practice in the same year by the adoption of a General Administrative Provision (GAP) on the above-mentioned regulation.

Discussing the details of this highly controversial regulation and its no less controversial GAP would go beyond the scope of this paper. However, one sentence should be quoted from the GAP because it is crucial. Paragraph 2.3 of the GAP adopted on November 26, 1984 reads as follows:

»... based on the geological, hydrogeological and hydrological data, and against the background of requirements in terms of tapping and production technology, as well as in the light of physical, physico-chemical and microbiological data on the nature of the mineral water involved, there must be no indication of a potential risk of man-made contamination (e.g. waste dumping sites, mining, agriculture) ...«

IV.

However, it is these very sources of contamination that must be expected when prospecting for mineral water in coal-mining areas, except for agriculture with its exorbitant use of nitrate fertilisers. What makes things worse is that there are extensive residential and industrial settlements in such areas, which may make it difficult to find a suitable point for sinking a well.

The Ruhr area is a good case in point because it is an industrial conurbation that causes a lot of problems when it comes to exploring sources of natural mineral water. It is an area which has been subject to heay industrial use for more than 150 years and where mining has been practised since the early nineteenth century - an area whose subsoil has been prevented from being used as a water reserve facility because it has been perforated by countless mines.

Although millions of cubic meters of drained pit water have made the Ruhr area the largest »mineral spring region« in the world, the »mineral water« involved consists of highly concentrated brine blended with every conceivable form of liquid and more or less volatile hydrocarbons. The large-scale draining measures carried out to ensure the operability of the mines have also lowered the water table in large parts of this carboniferous rock region. In many places, exploratory wells would come across groundwater of dubious quality only at a depth of 40 meters or more.

Unfortunately, the mining authority imposes certain restrictions on the geologists' curiosity: permission to carry out drilling operations that proceed below a depth of 100 meters is subject to approval of a »plan of working«

which must be submitted to the mining authority. Such plans rarely meet with the authority's approval.

In areas with industrial facilities that require human labour, there is a high density of residential settlements. In the Ruhr area - or to be more precise, in the conglomerate of local authorities designated as Ruhr area - the total residential and working population amounted to 5,215,692 people in 1984, i.e. 1,233 inhabitants live on 1 square kilometer. They live in 744,420 residential buildings with a total of 8,990,909 living rooms. 616,182 inhabitants of the Ruhr area are employed by 2,449 companies alone, operating in the fields of mining, iron and steel production, steel processing, surface finishing, aviation and aeronautics, etc.

Over the past 150 years, industrial plants based in this area have repeatedly dumped and covered their waste - both toxic and non-toxic - in a totally uncontrolled manner on their own premises, and have then forgotten about it. Owing to this practice, there are many places in the Ruhr area today with concentrations of highly toxic substances that are severely harmful for human health. In addition to extremely high concentrations of heavy metals, hydrocarbons are present in the form of all conceivable chemical compounds. Benzene, toluene, xylene, napthalene, fluorene and similar substances can be detected in amounts which, in some instances, exceed the maximum limits laid down in the German Drinking Water Regulation (TVO) by a factor of 1,000 (TVO limit representing the sum of 6 pilot substances: 0.2 µg/l).

If these or similar substances show up in the chemical analysis of a given mineral spring whose operation must then be stopped, in most cases it is not possible to sink a substitute well in the immediate vicinity of the current production site, because this is usually prevented by the small sizes of lots in the Ruhr area and the ensuing complicated distribution of land property.

In cases where a charted fault hampers contamination progress or where such a fault makes progress altogether impossible, it is generally not possible to sink a new well because of the prevailing property situation. The land is simply used for other purposes.

V.

In spite of all these obstacles, however, there are cases when prospects for sinking a well are quite promising. This is due exclusively to the geological set-up of the Ruhr area.

North of the so-called »Ruhrschnellweg«, which is a trunk road connecting the cities of Dortmund and Mühlheim on the Ruhr, the subsoil consists of Upper Cretaceous rock formations, which in this area discordantly supersede Palaeozoic formations characterised by multiple folds and faults. The Palaeozoic formations dip gently towards the north so that the thickness of the overlying Cretaceous rock increases towards the north (see figures 1 and 2).

Towards the west, the Upper Cretaceous rock increasingly assumes a border sea facies character (Bochum Greensand, decreasing lime content in the Labiatus layers passing into an argillo-marlaceous facies, Essen Greensand), leading to substantial variations in thickness and facies, and hence, widely varying water routings inside the caprock.

In the east of the Ruhr area, the Labiatus layers partly act as fairly good aquifers, while in the western parts which show an argillo-marlaceous character, these layers act as an impermeable bed.

At some points, the Bochum Greensand is 25 m in thickness, whereas - just a few meters away - it is only 10 m thick. The thickness of the Essen Greensand varies between 0.5 and 10 meters.

Owing to the earlier-mentioned supraregional draining of mine water, the broken Palaeozoic formation, which had been subject to considerable tectonic stress, is not a suitable supplier of groundwater or mineral water. Many a well builder ran into big trouble when drilling into this »sponge« after sinking his well through the unpredictable Essen Greensand.

VI.

In this local environment, only the groundwater storeys of the caprock are potential mineral water sources. In the south-western part of the Ruhr area, three groundwater storeys may be distinguished:

The first one is found in sandy or gravelly layers of Quartenary/Tertiary origin. It is about 5 meters in depth. Figure 3 shows a 3-D computer graphics representation which very impressively illustrates the extent and profile of this storey. Unfortunately, however, this does not provide much information on the configuration of lower groundwater storeys.

The second one of these storeys extends to about 30 meters of depth with regional variations. It is separated from the underlying stratum by impermeable argillo-marlaceous beds which consist of green sand and sandy/clayey marl of Upper Cretaceous Coniacian origin.

The third groundwater storey extends from the Lower Coniacian »Schloenbachi« layers via the Bochum Greensand and the Turonian Labiatus layers down to the Cenomanian Essen Greensand. The Cenomanian stratum is separated from the underlying Palaeozoic formation by a conglomerate of brown haematite.

VII.

The first groundwater storey does not qualify as a potential source of mineral water because, due to the industrial pollution loads mentioned earlier, there is a high risk that all superficial waters are contaminated.

The second groundwater storey can only be regarded as a potential source of mineral water in those cases where the regional facial character of the rock formation acts as a barrier that stops contamination not only from a vertical but also from a horizontal direction, i.e. if it prevents contamination that follows layer dipping, e.g. in the form of compact argillaceous marl.

This leaves the third groundwater storey which consists of limestone, calcareous marl and green sand. In this storey, there are, indeed, good prospects for successfully discovering mineral water that complies with the requirements laid down in the Mineral and Table Waters Regulation. This storey is sealed off from the upper bed by means of argillo-marlaceous rock. These argillo-marlaceous beds have been found during drilling operations in large parts of the Ruhr area, and they have also been demonstrated by means of geophysical logging.

Apart from the fact that the overlying argillo-marlaceous beds protect this groundwater storey from man-made contamination in vertical direction, the fine green sands provide excellent protection from contamination due to their very effective filtering action. Hence, there is a high likelihood that waters coming from this storey will be largely free of contamination.

VIII.

All the statements made above can be substantiated by observations from two wells (see figure 4).

The first well (A) was initially sunk to the boundary between Emsch marl, Coniacian and Turonian Schloenbachi layers. The argillo-marlaceous beds expected were in fact found and confirmed by means of geophysical logging of the »Westfälische Berggewerkschaftskasse« (WBK). Squeeze cementation was then applied below the argillo-marlaceous rock in order to seal off the upper groundwater storeys. Following this operation, the well was sunk to its final depth.

After several weeks of pumping, water samples were taken and analysed. They did not show any contamination (measuring accuracy: 0.001 µg/l). Total dissolved solids proved to be at a level that offered nutritional benefits. Hence, this water complies with the requirements laid down in the Mineral and Table Waters Regulation for natural mineral water. Since the thickness of the green sand layers at this particular point was not typical, it was decided to drill a second well (B) using the same procedure as before: after sinking the well to a point below the argillo-marlaceous bed, the upper bed was once again sealed off by means of squeeze cementation, and the well was then sunk to its final depth. After several weeks of pumping, comprehensive chemical analyses showed that the water was free of man-made contamination and beneficial from a nutritional point of view. The water involved thus qualifies as »natural mineral water«.

It has been shown that it is possible - despite the earlier mentioned disastrous effects of massive human presence on nature - to find »natural mineral water« in a highly industrialised region such as the Ruhr area, and to recover and use this water.

However, this requires a given geological set-up of the subsoil, a given lithology and - as demonstrated in the example above - the presence of a supraregional impermeable bed that shields the mineral water from contamination. It is only by intensive studies of the geology of a given area, by screening old and new publications on the area involved, by comparing existing well profiles, by evaluating large amounts of geophysical documents and by being informed about major industrial operations in the immediate vicinity and further away that it is possible to be successful in sinking a well in such or similar areas which are subject to heavy human use.

Fortunately, there is one potential source of man-made contamination that only plays a minor role in the Ruhr area: agriculture. NO_3 concentrations in water are either very low or non-existent.

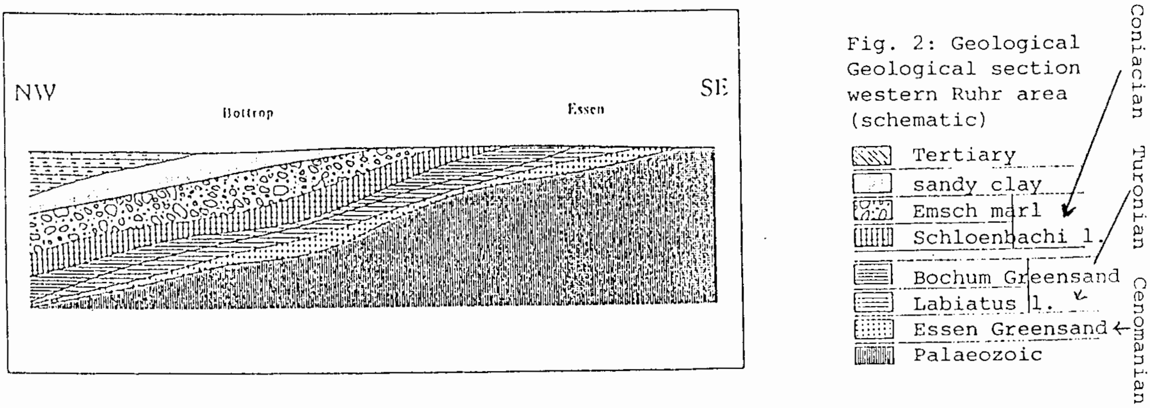

Fig. 2: Geological
Geological section
western Ruhr area
(schematic)

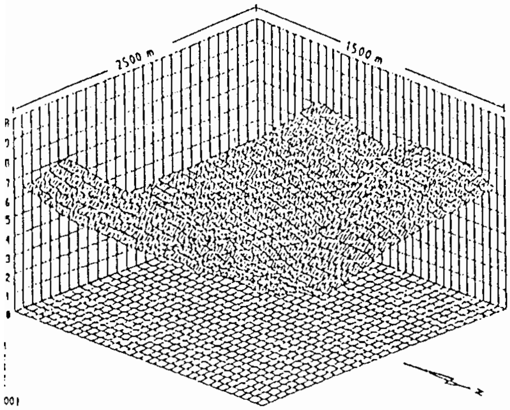

Fig. 3: Surface area of first ground-water storey in the area of Essen - Wattenscheid

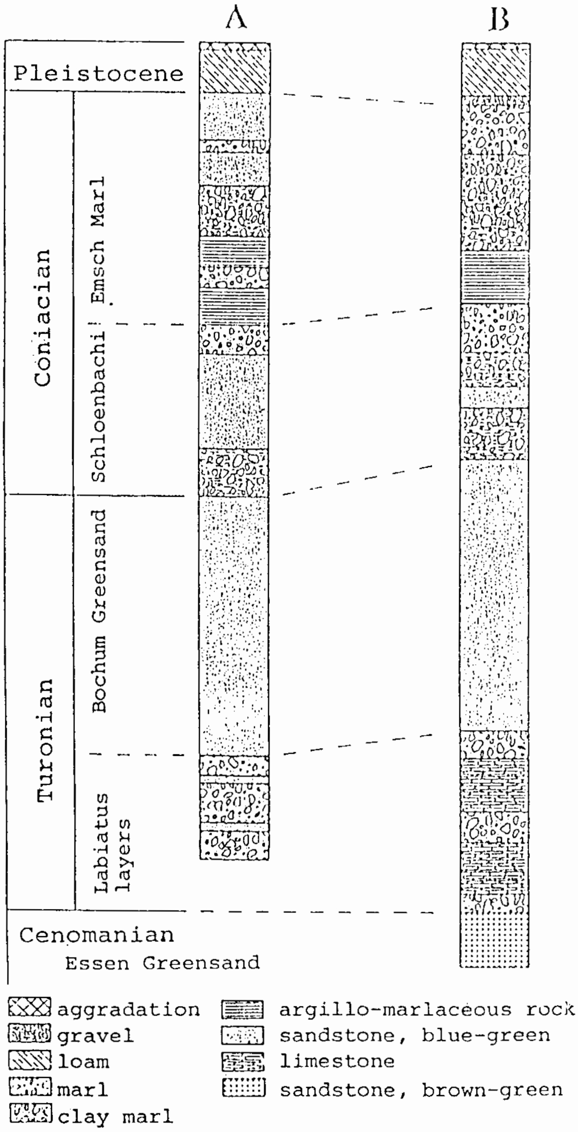

Fig. 4: Geological well profiles SW Ruhr area