Re-disposal of old exploitation wells – potential sources of environmental pollution in abondoned hydrocarbon deposits of the Czech Republic

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Ponowna likwidacja starych odwiertów eksploatacyjnych – potencjalne źródła zanieczyszczenia środowiska w nieczynnych złożach węglowodorów w Republice Czeskiej. Prz. Geol., 66: 379–387.

A b s t r a k t. W artykule omówiono ważny problem ochrony środowiska w rejonie złóż ropy i gazu, którym ostatnio poświęcano wiele uwagi. Obecność starych, niedostatecznie uszczelnionych lub całkowicie nieuszczelnionych otworów wiertniczych, wcześniej wykorzystywanych do eksploatacji ropy i gazu ziemnego, jest poważnym zagrożeniem. W Czechach, na Południowych Morawach (obszar eksploatacji węglowodorów zarówno w przeszłości jak i obecnie), istnieje bardzo wiele (setki) otworów eksploatacyjnych. W materiałach archiwalnych bardzo trudno (często wręcz niemożliwe) jest znaleźć informacje na temat zarówno sposobu zakończenia eksploatacji w tych otworach, jak i zastosowanych procedur ich likwidacji. W trakcie niedawno prowadzonych badań i prac nad ponowną likwidacją otworów stwierdzono, że wiele z nich było zlikwidowanych nieodpowiednio i nieprofesjonalnie, a niektóre nadal nie zostały zlikwidowane. Stwarza to znaczne zagrożenie dla obszaru Południowych Moraw, w szczególności dla źródeł wody pitnej oraz rolnictwa (Obszar Chroniony Naturalnej Akumulacji Wód – CHOPAV, Czwartorzęd Rzeki Morawy). Co więcej, jest to poważne zagrożenie dla obszaru występowania bardzo cennych biotopów. Artykuł omawia możliwości usunięcia tych ekologicznych zagrożeń na obszarach złóż węglowodorów poprzez recykling dawnych otworów eksploatacyjnych będących źródłem zanieczyszczenia gleb i wód. Podobne problemy z pewnością pojawiają się na obszarze Polski, gdzie intensywnie eksploatowano znacznie więcej złóż, a otwory istniały już w XIX w., w okresie kiedy zarówno wiedza o procedurach likwidacji otworów wiertniczych, jak i świadomość znaczenia właściwego uszczelnienia starych otworów były niewielkie.

Słowa kluczowe: ropa naftowa i gaz ziemny, powtórna likwidacja, zanieczyszczenie, źródło wody pitnej, ekologia

A b s t r a c t. This article deals with a significant issue of environmental protection of oil and gas deposits that have recently drawn a considerable attention. The presence of old insufficiently sealed or entirely unsealed wells, formerly serving a purpose of oil and natural gas extraction, pose a significant threat to the environment. In the South Moravia region of the Czech Republic (an area of hydrocarbon extraction both in historical and recent times), there is a significant amount (hundreds) of production wells. It is very difficult or often even impossible to find information in archival materials on the cease of extraction from these wells and on the system of abandonment procedures applied. During the recent surveying and re-abandonment works, it was found that many wells had been abandoned inadequately and unprofessionally, and numbers of wells still have not been abandoned at all. This poses a considerable risk to the South Moravian landscape, especially to the sources of drinking water and to agriculture (to the Protected Area of Natural Water Accumulation – CHOPAV, Morava River Quaternary). Furthermore, it is a significant threat to the areas where extremely valuable biotopes occur. This article discusses the possible disposal of these ecological hazards to the areas of hydrocarbon deposit occurrences through recycling of old drawing wells as potential pollution sources of soil and water. Similar problems have certainly appeared in the Polish territory, where intense extraction took place at a far greater number of deposits, and where the wells already operated in the 19th century, in days gone by when there was little knowledge of abandonment procedures and little awareness of proper old well sealing.

Keywords: *oil and natural gas, well re-liquidation, contamination, source of drinking water, ecology*

In 2007, the PKÚ state enterprise was appointed by the government's decree No. 713 with the task of disposing of environmental burden left by oil and natural gas exploitation, in responsibility to the state in the South Moravia region (Figs. 1, 2). Since 2010, remediation projects of contaminated sites (SEZ) has been implemented (Propagační materiál PKÚ, 2014; Slivka, Bujok, 2017). The SEZ covered former exploration and extraction in oil and gas wells, insufficiently or inadequately abandoned, remains of exploitation technology (e.g. oil collection areas, oil joints), and sites contaminated due to the oil exploitation. They originate mainly from the period of 1925–1965. The depth of these wells varies approximately from 115 m to 2670 m (Čomaj, 1989; ČiŽmář, 2004; Ďurica, Suk, 2011). Oil and natural gas exploitation has continued in the South Moravia region with varying intensity and under the operation of various exploitation companies until the present days. Currently, the research and extraction companies operating in the area are: MND a.s., MND Drilling & Services a.s., MND Gas Storage a.s., Lama Gas & Oil a.s. (formerly Česká naftařská s.r.o.), SPP Storage s.r.o, and Moravia Gas Storage a.s. Times change, but the oil and gas along with the problems connected with their exploitation remain the same. All of the companies represent the private sector, with no participation of the state. The overall amount of exploitation of oil and natural gas is relatively insignificant from the national economy viewpoint; however, for the above-mentioned private companies, it is still an interesting source of money.

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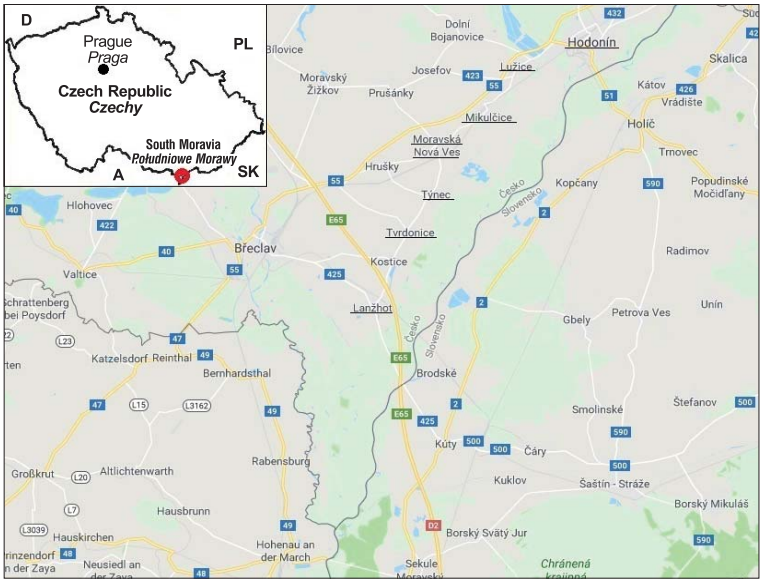

Fig. 1. Location of the region of interest within the Czech Republic (South Moravia) (https://maps.google.cz)
Ryc. 1. Lokalizacja obszaru w obrębie Czech (Południowe Morawy)

SOURCES OF DRINKING WATER IN SOUTH MORAVIA

The areas around the Morava, Kyjovka and Dyje rivers are included in the Protected Area of Natural Water Accumulation – the Morava River Quaternary (CHOPAV), proclaimed by the government decree No. 85/1981 Sb. of the Czechoslovak Republic (Fig. 2). It is typical of CHOPAV that the conditions for using the surface and underground water sources are very favourable (Propagační materiál PKÚ, 2014)

The groundwater resources have been extensively used by the intake area of Moravská Nová Ves (1547 ha), which has been operational since 1988. The water accumulation used is limited to the groundwater reserves in the saturation zone of the Quaternary bottom sediments (sands, sandy gravels and gravels). The Lednice intake area is located east of the village of Lednice and borders the Břeclav Kančí obora intake area (Fig. 2).

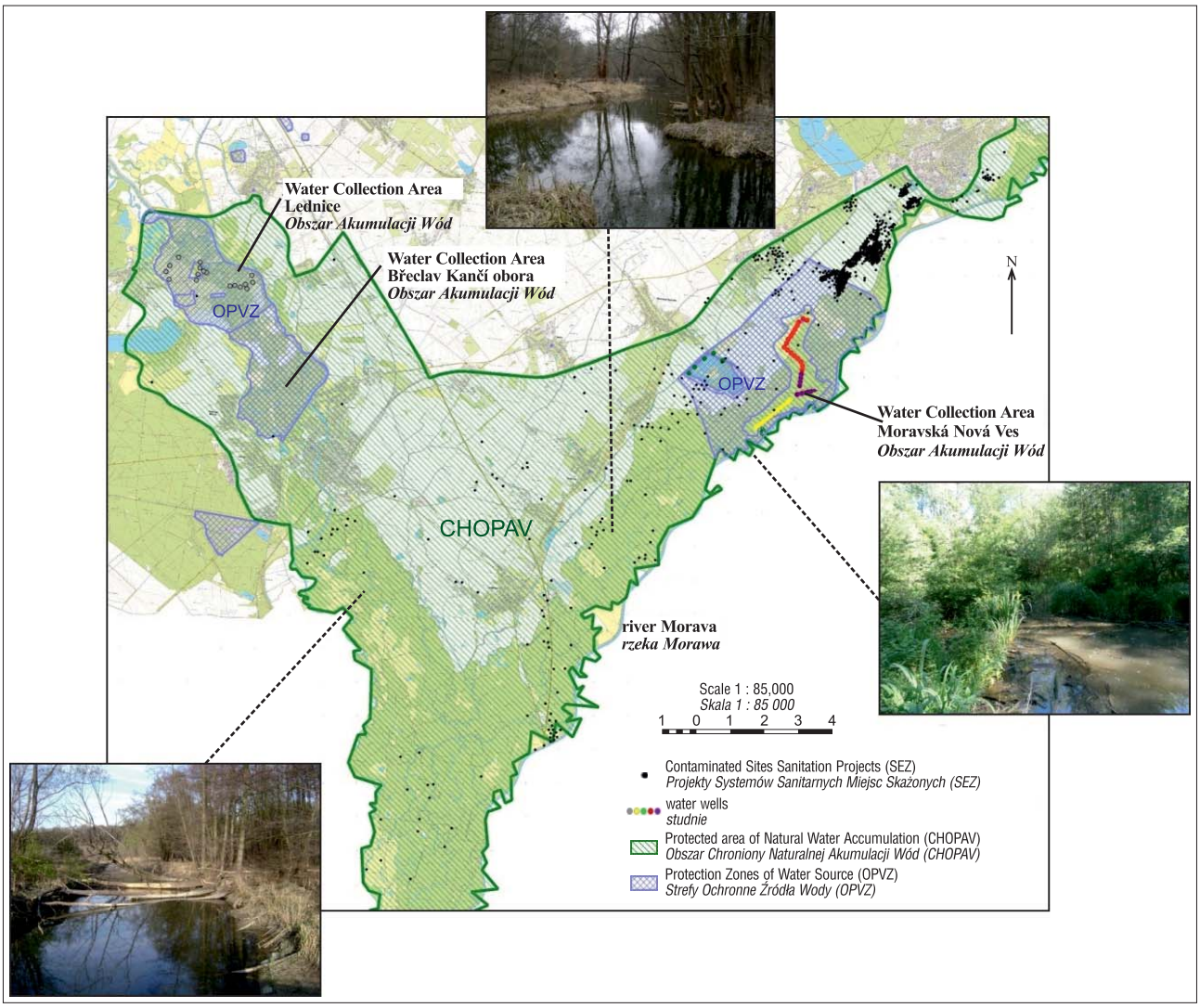

Fig. 2. Map of the CHOPAV – the Morava River Quaternary area of interest, and the oil deposits called Staré Pole u Nesytu and "Elevation South" (Propagační materiál PKÚ, 2014)
Ryc. 2. Mapa obszaru CHOPAV – czwartorzęd rzeki Morawy, oraz złoża ropy Staré Pole u Nesytu i „Elevation South" (Propagační materiál PKÚ, 2014)

The CHOPAV Morava River Quaternary is in great danger because of the oil deposits, whose exploration has begun at the beginning of the 20th century. The extent of exploration and extraction is considerable (Figs. 3, 4). Old contaminated sites (SEZ), after exploitation of oil and natural gas, are marked in black in the map section pictured in Figure 2.

The CHOPAV Morava River Quaternary is considered an area worthy of exceptional protection, not only for the reasons implied by water resources protection, but also in the context of landscape and ecosystems protection. Most of the CHOPAV Morava River Quaternary area falls under the list of protected areas NATURA 2000, with the presence of endangered species.

Specially protected areas are also found in the CHOPAV Morava River Quaternary area (Fig. 2), for example the Skařiny nature reserve (NR), which is an important area for ornithologists, the Stibůrkovská Lakes NR with riparian forests, and the Morava River billabongs, or the natural landmark Očovské Meadows near Hodonín, with its sedge meadows. In the area between the Morava and Dyje rivers, there is the Ranšpurk national nature reserve (NNR) with an ancient riparian forest. The Mikulčický Luh nature park (NP) represents a typical example of floodplains and is an important ornithological area. Another important avian area is the Tvrdonicko Conflux, which is the only rookery for some species in the Czech Republic. The Niva Dyje NR comprises not only a floodplain with riparian forests and solitary oaks, but also the Lednické Ponds NNR and several avian areas. The PodluŽí Confluence is a unique riparian forest locality of European-scale importance, part of it even has the character of ancient forest growth (Propagační materiál PKÚ, 2014).

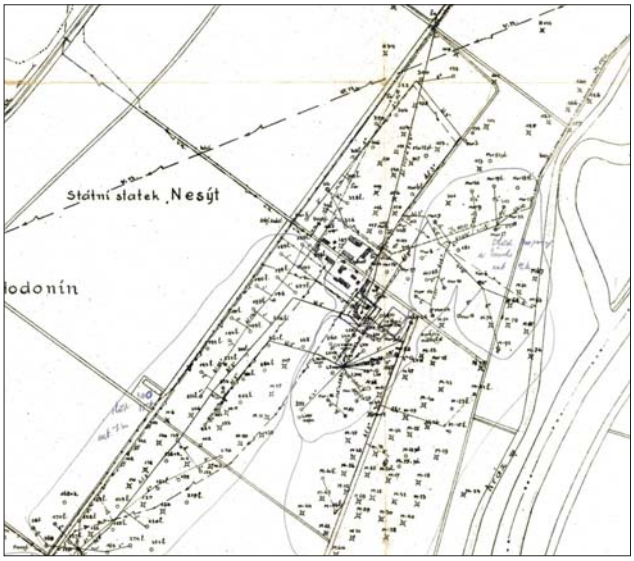

Fig. 3. Wells and collection points in Staré Pole near Nesyt u Hodonína (approx. 1920–1930) (Propagační materiál PKÚ, 2014)
Ryc. 3. Otwory wiertnicze i punkty zbiorcze, Staré Pole k. Nesytu u Hodonína (ok. 1920–1930) (Propagační materiál PKÚ, 2014)

EXPLOITATION HISTORY IN THE CHOPAV REGION

The region between Hodonín and Moravská Nová Ves hosts the greatest number of extraction wells concentrated within such a small area in the whole of Czech Republic, see Fig. 2. Exploration of oil deposits near Hodonín (Staré Pole area) commenced in 1919 in the vicinity of Nesyt court (Figs. 2, 3 and 4). The rich oil deposit near Ratíškovice was found in the same year and, according to the reports from that period, it was "a discovery of geological key to Moravian treasure-chest, the Moravian Pennsylvania". This was referring to the historical period of the so-called "Pennsylvania oil rush", which, equivalent to the "gold rushes", broke out in the USA after discovering the oil deposits by "lieutenant" Dreyk in 185 (ČiŽmář, 2004). Shortly before the Second World War, there had been a total of 271 wells drilled at the Staré Pole deposit. Drilling operations continued in the area until the end of the 1950s. In the 1940s, a deposit called "Elevation South" was explored between the Morava and Kyjovka rivers near Mikulčice (Fig. 2). More than 500 oil wells have been drilled in this area. The extraction wells found in Staré Pole and "Elevation South" are approx. 180 to 950 m deep, with production zones found mostly at 400 m depth. The wells at the LuŽice and Týnec (Figure 2) deposits are substantially deeper (approx. 850 to 1580 m deep). Extraction works were ceased in that area the 1970s (Bednaříková et al., 1984; ČiŽmář, 2004; Propagační materiál PKÚ, 2014).

A significant number of the wells were abandoned during the process after reaching the economic limit. It was

Fig. 4. Exploitation works in Staré Pole near Nesyt at the beginning of the 20th century (ČiŽmář, 2004)
Ryc. 4. Prace eksploatacyjne, Staré Pole k. Nesytu na początku XX w. (ČiŽmář, 2004)

not the complete depletion of technologically extractable reserves, but the cost-ineffectiveness that brought the extraction works to an end. At that time, numbers of wells were left. There was still residual pressure releasing small amounts of oil flowing out with the formation water through the well mouth.

ABANDONMENT OF EXPLORATION AND PRODUCTION WELLS

The assessed wells were drilled as the exploration wells (verification of the possible presence of new deposits) or as the production wells – when already discovered deposits were opened (Fig. 3).

Negative exploration wells were closed or set for closing (not all the documentation has been preserved). Positive exploration wells were forwarded to production and mostly served this purpose until fully extracted. The wells, one after another, were then decommissioned and sealed, although sometimes a considerable time period elapsed between the cease of production and the final abandonment procedure. The procedures were often performed in a very primitive manner (by piling food or soil in the hole or ripping out parts of the casing), or in a manner lacking quality and methodical approach. Significant part of boreholes had been left in place, and improperly sealed even after being decommissioned. All the wells and related equipment, which had to deal with oil and were decommissioned before privatization of the original state corporation Moravské naftové doly – MND (Moravian Oil Mines), are now (current law of the Czech Republic) considered to be old contaminated sites (SEZ) (Bednaříková et al., 1984; Ďurica, Suk, 2011; Propagační materiál PKÚ, 2014).

Abandonment of the exploitation wells of oil and natural gas presents a serious technical problem and is often challenging in terms of time and technical and financial demands. Nevertheless, it is essential to give it appropriate attention.

The aim of abandonment of old wells is primarily to provably seal all the opened extraction and non-extraction aquifer formations, so that mobile fines could never, under any circumstances, come to migration from the formations located along the original casing (both outside and inside), or through the uncased sections of the annulus towards the surface (Bujok et al., 2001, 2012; Bujok, Rado, 2002).

For a long time there was no regulation issued by the "Czech Mining Authority" which would be concerned specifically with the issue of wells abandonment. Generally, in the recent past, "Decrees" or "Ordinances" issued between 1980 and 1986 were consulted as the ultimate authority. Presently, the amended Ordinance No. 239/1998 (Vyhláška ČBÚ...) is in effect (and has been since 1st June 2011), which deals with well abandonment requests in § 71b, 71c, 71d and in Annexes 5 and 6. It is necessary to abandon wells only on the basis of executing documentation worked out in detail by a planner with valid certification. All the mining regulations and laws must be obeyed during the extraction works, especially the principles of well abandonment, contents of tamponing and grouting cement mixtures, the use of separation fluids, and techniques and technology used for additional repair works on technical state of the wells and their casing.

Wells have to be abandoned in accordance with the executing technical project, respecting the principles of all the typified technological procedures. Taking into account that some of the wells are located in areas receiving extensive environmental protection because of the presence of important water sources, the executing projects must fully respect the statements of administration and pay increased attention to meeting all the requirements implied by the water resources law.

In Poland, the issue of well abondonment is governed by the regulations included in Geological and Mining Law and the ordinances of the relevant ministries (Ministry of the Environment) (Geological and Mining Law, 2011)

RE-LIQUIDATION OF IMPROPERLY ABANDONED WELLS

The literature relating to the issue of re-abandonment of old extraction wells (Sidorová, 2001; Guo et al., 2007; Slivka, Bujok, 2011; Stryczek et al., 2013), implies that the primary abandonment procedures were not always successful and that pathways of inter-zonal communication may still exist between the deposit and the surface (or the subsurface permeable formations), which allows way to migrate up the well. Such a situation might have occurred, for example, if the production casing was not cemented over the conductor casing shoe, then shot off above the assumed cement head outside the casing, and subsequently fully or partially extracted. A part of the annulus would then be left without any protective isolation and in the event of cement bridges (above the last perforation and at the mouth) or annulus being loose; the formation fluids could permeate to the surface (Fig. 5). Non-localized wells (or more precisely wells impossible to be localized) cannot be expected to have cement bridges at the mouth, and if the casing along the whole length of the well was extracted, there will not be any bridges even in the "bottom" part of the well and the migration of formation fluids may be more intensive.

Re-abandonment means a repeated abandonment procedure applied to old wells, consisting of reliable tightening of the well in order to prevent not only any future migration of contaminants (oil, formation water, gas) to the ground surface, but also their outflow into other underground formations and subsequently into the groundwater resources (Figs. 5 and 6).

Figure 5 presents the possible ways of contamination by oil and salty formation waters from extracted deposits. Fluids travel from the extracted zones up the untightened or inadequately tightened well towards the ground surface. The well is rigged with steel casing. These steel pipe sections can be eroded by the lateral geostatic pressure, aggressive salty waters, corrosion or even simply time itself (Figs. 5A and 5B). Formation fluids might leak through eroded casing of an inadequately abandoned well into the formations or even into the surrounding area on the surface, and thus contaminate, for example, the sources of drinking water. Figures 5 and 6 also show a lignite bed. In the area described, extensive mining activity was also carried out in the past, focusing on the mining of lignite.

Figure 6 presents how the old wells are abandoned. First, the migration of fluids into the wellbore is prevented.

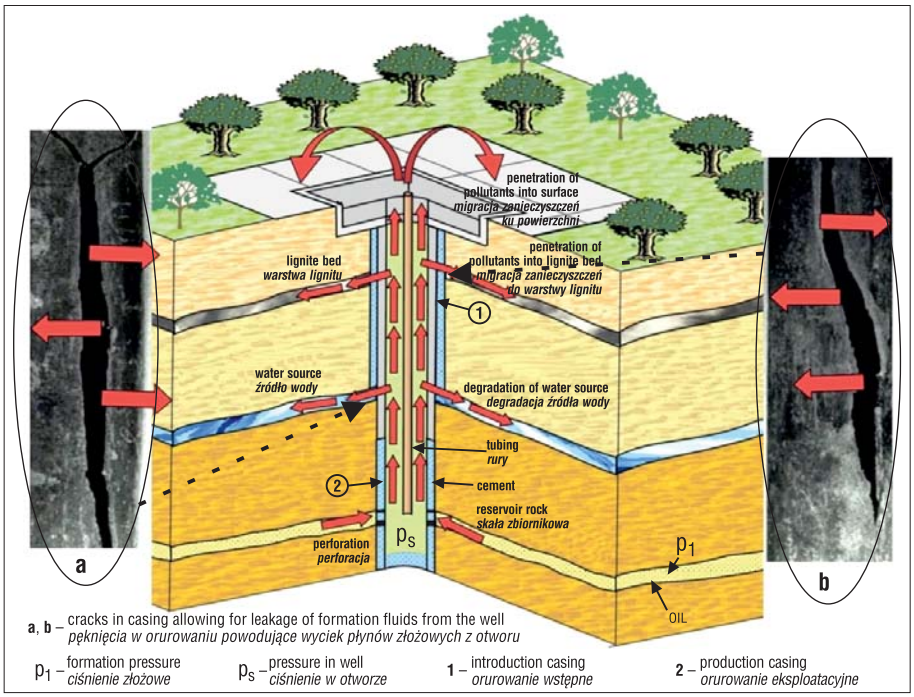

Fig. 5. Possible ways of contamination spread through an old, un-abandoned well. Lignite bed is presented on purpose. Intensive mining of lignite took place in the described area in the past (Propagační materiál PKÚ, 2014)

Ryc. 5. Możliwe sposoby rozprzestrzeniania się zanieczyszczeń poprzez stare, niezlikwidowane otwory wiertnicze. Warstwę lignitu przedstawiono celowo. W przeszłości na omawianym obszarze miało miejsce intensywne wydobycie lignitu (Propagační materiál PKÚ, 2014)

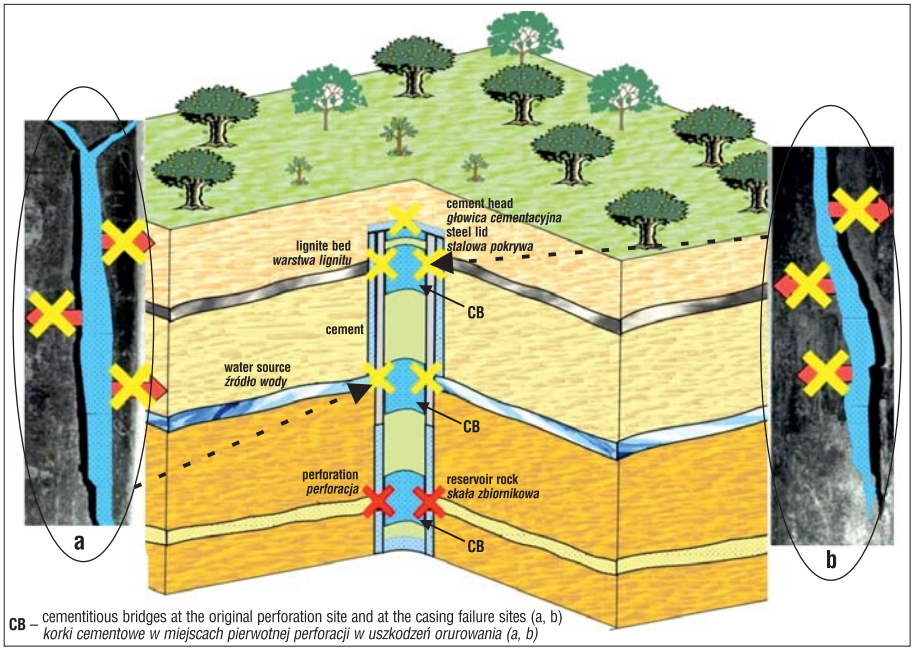

Fig. 6. An exemplary professional abandonment of an old exploitation well (Propagační materiál PKÚ, 2014)

Ryc. 6. Przykładowa profesjonalna likwidacja dawnego otworu eksploatacyjnego (Propagační materiál PKÚ, 2014)

This is performed by squeezing the cement slurry in place of the extracted formation through the original perforation (squeeze cementation) (Guo et al., 2007; Robello, Xiushan, 2009; Stryczek et al., 2013). After the cement hardens, the cement head is checked and tested for being hermetically sealed by pressurization and de-pressurization. Furthermore, it is necessary to re-cement the cement bridges and eroded places on the casing and all the possible formations (Figs. 6A and 6B), which are potential sources of future contamination, in accordance with the logging measurements. The cement head is re-checked again and tested for being hermetically sealed by pressurization and de-pressurization. Finally, a cement bridge is made at the mouth of the well, casings are cut off under the surface and a steel lid is welded in place, on top of which a cement cap is made. The implementer's conditions for re-abandonment procedures make use of type BIR and DIR drilling rigs (Fig. 7 presents the DIR 5505 drilling rig).

An example of the real abandonment of the H 289 well in 1965 and its re-liquidation in 2014 is shown in Figure 8A and 8B and in the legend to the figures.

Method of abandonment of the H 289 well, used in 1965 (Fig. 8A). Original borehole design – introduction casing 9 5/8" (244.5 mm), production casing 6 5/8" (168.3 mm), A1 – cement head behind introduction casing to the surface, A2 – bottom part of introduction casing 9 5/8" (244.5 mm) at a depth of 33.5 m, A3 – mud 1.18 kg/dm^3, A4 – cement head behind production casing at a depth of 220 m, A5 – cement head in production casing at a depth of 351 m, A6 – bottom part of production casing 6 5/8" (168.3 mm) at a depth of 359.3 m, A7 – final depth 380 m, A8 – cement bridge at the upper part of well, A9 – clay plug, A10 – perforated interval 348.5–333.2 with 68 blows (perforated interval), in ottnang inflow of oil. The well is physically destroyed. It was thrown by clay (A9). The upper part of well was cemented (A8). The well details were not documented. This method of disposal was not sufficient. The perforated interval through the collector layer (A10) was not insulated with a cement bridge. It has threatened the possibility of oil spills (Fig. 5) in the vicinity. For these reasons, re-liquidation was undertaken.

The method of re-liquidation of the H 289 well in 2014 is shown in Figure 8B. The well was searched, kicked off, and equipped with a new head. It was further cleaned to a depth of 351 m (B5) using the DIR 5505 drilling rig (Fig. 7). Subsequently, part of the production casing cage

Fig. 7. Re-abandonment of the H-RIM70 well using the DIR 5505 drilling rig, Staré Pole near Nesyt (Propagační materiál PKÚ, 2014)
Ryc. 7. Ponowna likwidacja otworu H-RIM70 z wykorzystaniem urządzenia wiertniczego DIR 5505, Staré Pole k. Nesytu (Propagační materiál PKÚ, 2014)

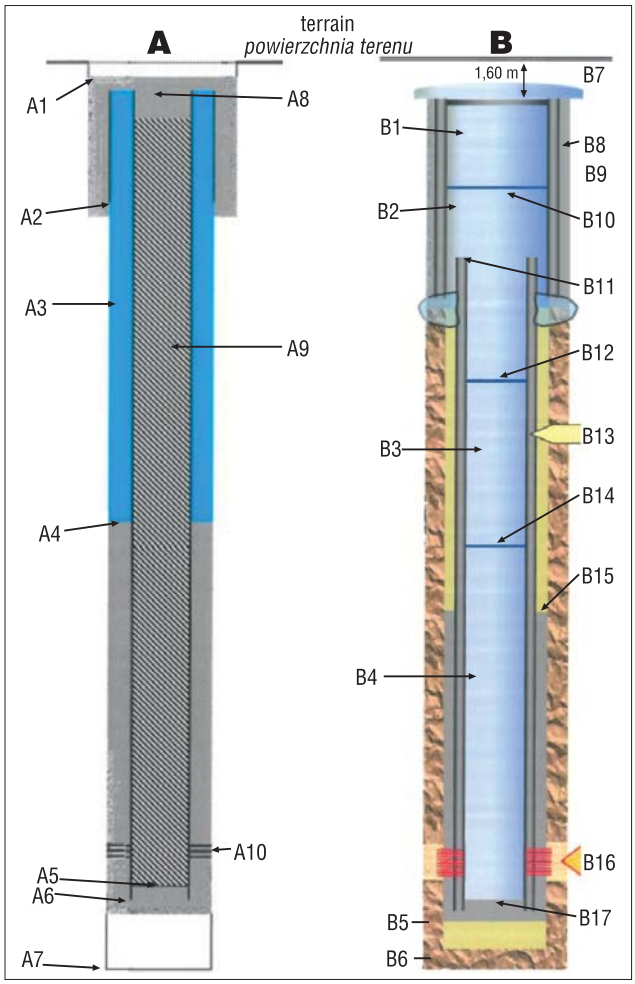

Fig. 8. Well H 289. **A** – situation after abandonment in 1965; **B** – situation after re-liquidation in 2014
Ryc. 8. Otwór H 289. **A** – sytuacja po likwidacji w roku 1965; **B** – sytuacja po powtórnej likwidacji w 2014 r.

was cut and pulled (B11). The well was isolated by four cement bridges (B1, B2, B3, B4). After dismantling the drill rig, the upper part of well was kicked to a depth of 1.8 m and the casing was burned at a depth of 1.6 m under the terrain. A 10-mm-thick steel plate was welded onto the stump of the burning casing of the introduction casing. A cement „hat" was made above it and the rest of the pit was covered with earth (B7). The terrain has been restored to its original state.

B1 – cement loose bridge; B2 – cement pressure bridge; B3 – cement loose bridge; B4 – cement pressure bridge; B5 – well depth cleansing depth 351 m; B6 – original drilling depth of the well was 380 m; B7 – steel plate and cement "hat"; B8 – cementation of the introduction casing to the surface; B9 – introduction casing 9 5/8" (244.5 mm), wall thickness 8.9 mm, covered in an interval of 1.6–33.5 m; B10 – certified "head" of the cement pressure bridge (B2) at a depth of 9.5 m; B11 – Cumulative Cylinder Cutting Exit Column 6 5/8" (168.3 mm) depth 22 m; B12 – verified "head" of the cement loose bridge (B3) at a depth of 56.35 m; B13 – production casing 6 5/8" (168.3 mm), wall thickness 7.3 mm, residual length of casing in the range of 22.0–350.3 m; B14 – verified "head" of the cement pressure bridge (B4); B15 – determined level of initial cementation behind production casing (193 m); B16 – interval of the original perforation (348.5–333.2 m) of the target production horizon, number of blows 68; B17 – original "head" of the cement bridge at the bottom of production casing (depth 351 m).

When assessing the necessity of abandoning old production wells, it is sometimes implied that abandonment of old wells is not necessary and that there can be no inter-zonal communication between the layer and the surface, as in time it comes to an irreversible collapse of the original wellbore's annulus under the impact of lateral horizontal geostatic pressure (an equivalent to "ingrowing" of the work in classic, particularly coal mining, activities) especially in places with occurrence of clays or claystone, if you like. Were this statement universally valid, we should encounter no oil contamination in the surface formations of the old abandoned wells, or the groundwater or any gas manifestations on the surface. Our laboratory researches (Bujok et al., 2012, 2013, 2015) prove (Fig. 9) that the postulate is not universal. This is also substantiated by the check days' reports of "Contaminated Sites Sanitation with Inadequately Abandoned Oil and Natural Gas Extraction Wells in Various sectors of the CHOPAV Morava River Quaternary", wherein records of surface contamination occur rather frequently (Figs. 10 and 11). It must be noted, however, that this contamination does not in all cases come from the formations through the above-mentioned mechanism, but in many cases it comes from completely different sources, which today is impossible to tell apart with absolute certainty. It could have happened for example while manipulating with the oil substances during the extraction process and flushing out the mobile fines into the mud pit during the pumping attempts. Still, it is possible to say that, when assessing the risks, we cannot exclude the contamination of surface formations by oil leaking through a well's loose annulus. It is necessary to take account; cases of oil overflowing (spontaneous outflow) through the well mouth into the terrain have been provably verified to take place during the re-abandonment procedures (Fig. 8) (Bujok et al., 2012; Propagační materiál PKÚ, 2014).

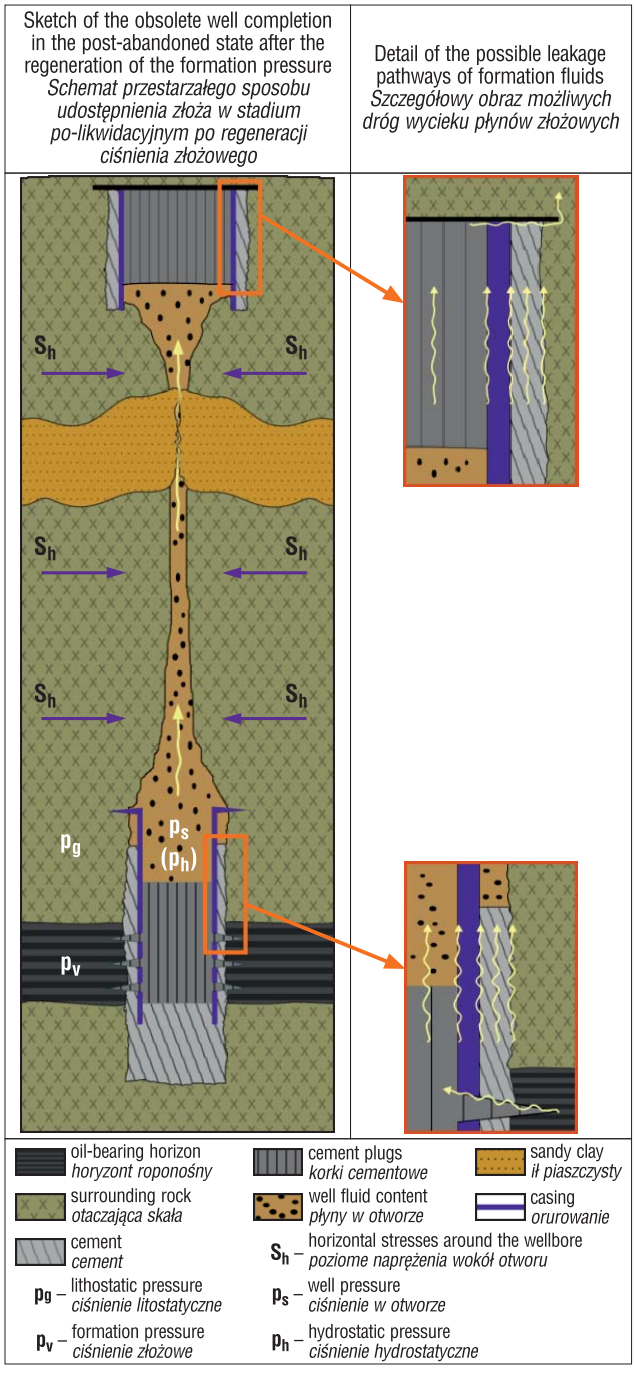

Fig. 9. The scheme of wellbore condition before the definitive re-abandonment procedure (Bujok et al., 2015)
Ryc. 9. Stan otworu przed procedurą ostatecznej likwidacji (Bujok i in., 2015)

CONSEQUENCES OF OIL EXPLOITATION IN THE CHOPAV AREA – THE MORAVA RIVER QUATERNARY

During the extensive hydrogeological exploration work in the described area (CHOPAV), carried out in 2005, 2007 and 2011, it was confirmed that old wells and relics after oil exploitation can be a permanent source of environmental pollution. In the past, the well facilities were mostly removed only from above the ground surface; however, in the subsurface parts the downhole equipment was left in place without essential professional abandonment procedures. The wellheads were in some cases only shot off or torn off without subsequent isolation. The soil and groundwater sources in the area surrounding a substantial number of wells are consequently polluted. After uncovering the upper part of some of the wells, oil was found to be flowing spontaneously out through (or past) the casing remnants (Figs. 10 and 11).

The PKÚ state enterprise designed (after being appointed by the government of the Czech Republic) an elaborate sanitation project SEZ for the sites contaminated by oil and natural gas exploitation in the southern part of the CHOPAV Morava River Quaternary. The complex project divided the CHOPAV Morava River Quaternary area into seven sanitation sectors according to the location. Implementation of the sanitation works in individual sectors lead to solving the SEZ issue in the whole area of interest (CHOPAV Morava River Quaternary). At the same time, environmental protection of the Natura 2000 locations, nature parks and other unique locations was secured in order to prevent further pollution, even in the case of extreme flooding (Propagační materiál PKÚ, 2014).

Sanitation works in the CHOPAV Morava River Quaternary comprised:

– specification of contamination extent in the surrounding area of the SEZ,
– re-abandonment of wells,
– sanitation of soils and groundwater resources contaminated above the level of sanitation limits suggested for the particular area,
– monitoring during and after finishing sanitation works.

To specify the extent of soil and groundwater contamination around the water collection areas, a network of shallow small-diameter unequipped wells was used for the research of contamination. These exploration wells were drilled to collect soil and water samples. The number of exploitation wells was modified according to the current needs so that it could document the extent of contamination area and its surroundings as precisely as possible.

The results implied that the soil and groundwater contamination in the area surrounding the SEZ exceeds the limits set by the Ministry of Environmental Protection. Limit concentrations "C" for remedial action in the case of NEL – non-polar and extractable substances, for groundwater 1000 µg/l for 1000 mg/kg solids) and considerably and due to its extent, it presents a great risk to both the groundwater and surface water resources, and to the whole ecosystems (Propagační materiál PKÚ, 2014).

Based on a measurement of contamination extent in the areas surrounding the SEZ, the soils contaminated above the limit value are excavated and oil is pumped away from the groundwater surface (Figure 11). These soils are then transported to disposal sites and the removed oil is transported, along with the contaminated water, in large cisterns to decontamination stations (Propagační materiál PKÚ, 2014).

In the territory of sectors I–VII of the CHOPAV Morava River Quaternary the following actions were implemented:

– 902 old environmental problems were localized,
– 19,531 exploitation wells were drilled,
– 205,937 laboratory analyses were made,
– 527 wells were re-abandoned,
– 593 remedial actions were carried out,
– 335,851 tons of over-contaminated soils,
– 8,530 tons of extracted hydrocarbon were liquidated,

Fig. 10. Uncovered wellhead of the improperly abandonment HG21 well with spontaneous outflow of oil (Propagační materiál PKÚ, 2014)
Ryc. 10. Odsłonięte ujście (głowica) otworu niewłaściwie zlikwidowanego wiercenia HG21 ze spontanicznym wypływem ropy naftowej (Propagační materiál PKÚ, 2014)

Fig. 11. An example of sanitation in the area surrounding the old re-abandoned wells. Contaminated soils are excavated, contaminated groundwater pumped away. Staré Pole u Nesytu (Propagační materiál PKÚ, 2014)
Rys. 11. Przykład systemu sanitarnego na obszarze okalającym dawny, powtórnie zlikwidowane otwory. Zanieczyszczone gleby są wybierane, a skażone wody gruntowe wypompowywane. Staré Pole u Nesytu (Propagační materiál PKÚ, 2014)

– 242,926 m^3 of contaminated groundwater were pumped,
– 923 m^3 of hydrocarbons were captured from pumped waters,

The length of temporary panel communications was 76 km, the operations took place on 12 territories, rescue archaeological research was carried out at 950 SEZs, archaeological finds were made near 3 SEZs, and a total of 474 control days took place.

A total of approximately EUR 252 million was spent on the implementation of the aforementioned activities.

CONCLUSION

The possible conclusion is that the data provided in the preserved documentation about the abandoned wells in sectors I–VII of the CHOPAV Morava River Quaternary did not correspond with the real state of things in any of the examined cases, as observed during the re-abandonment works. The most significant differences were found in data concerning the construction methods, quality and interval range of the cement bridges – which is the most important element securing the isolation of possible ways of contamination within the well annulus. This documents the fact that the abandonment procedures performed before 1998 in most of the cases are not able to reliably prevent the migration of fines between the formations or even between the formations and the surface.

Based on what was mentioned above, it is clear that the wells, in which inflow of formation fluids was observed during the drilling, or the formations saturated with formation fluids were perforated and subsequently used for production, may pose a potential threat to the natural environment (air, ground and surface waters, soils) due to inadequate/incomplete isolation of open formations by cement bridges or incorrect cementing of the casing, or possibly of other intervals (shoes, cut-offs...). This applies especially to the wells that opened reservoir formations with high hydrostatic pressure.

It is also possible to state that the examined wells may obstruct, or in some cases even do obstruct further usage of the area due to the possible presence of contaminants (formation fluids), which might leak through the insufficiently abandoned annulus and threaten the health and properties of the inhabitants.

At present, the PROJEKT has been prepared and approved to deal with the issue of replication also for wells located outside the CHOPAV area. Such probes are also over 500. The reuse will be done selectively, depending on the degree of risk to the environment.

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