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Microbial assisted waterflood effectively increases production from a mature Carpathian oil field: Project results and analysis of economic efficiency at eighty months

Nawadnianie mikrobiologiczne jako sposób zwiększenia stopnia sczerpania starych złóż ropy naftowej. Wyniki projektu i analiza efektywności ekonomicznej po 80 miesiącach trwania projektu

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ABSTRACT: This paper relates to the possibilities of applying Microbial Assisted Waterflood (MAW) technology in mature Carpathian oil fields. The geological structure of the Polish Carpathian Foothills is summarized, and a rational is given for continued use of microbial oil recovery technology in Polish Foreland reservoirs. Additionally, a recommendation is made to investigate the use of microbial oil recovery methods for other Carpathian reservoirs throughout the region where appropriate conditions exist. In support of this rational, the results from 80 months of an active MAW project at the Plawowice oil field are presented. Results of laboratory tests simulating the microbial flooding process at Plawowice have been presented earlier. From the beginning, the project was designed to economically improve the recovery factor (RF) from this depleted Carpathian Foreland reservoir. Phase I field work at Plawowice began in September, 2011. The initial bio-preparation was produced by INiG and delivered to the Plawowice oilfield. Once on site, it was further amplified in volume and then injected into the Pl-311 injector in one large slug. Phase II in September, 2014 is marked by microbial re-treatment and project expansion. In June, 2017 the project moved into Phase III and as of March, 2019 it is halfway into the 8th year of continuous operation. Proper design and implementation of MAW technology at Plawowice has proven capable of increasing production rates from all three oil wells currently involved in the MAW project. Production from the Pl-52, Pl-159 and Pl-111 oil wells all show significant increases in production substantially above their production rates before microbial treatment, with average values of these increments being 147%, 39% and 112% respectively. An assessment is made of the overall economic efficiency of the Project, concluding that an extension of the productive life of all project wells was achieved by phase III of the project.

Key words: MAW, Carpathian oil fields, Incremental Oil, Decline Curve, Microbial Assisted Waterflood, MEOR.

STRESZCZENIE: W artykule przedstawione zostały przesłanki do stosowania technologii nawadniania mikrobiologicznego mającego na celu poprawę stopnia sczerpania starych złóż ropy naftowej Karpat i przedgórza Karpat. Budowa geologiczna oraz warunki eksploatacyjne starych złóż ropy naftowej umożliwiają stosunkowo tanie wdrożenie technologii nawadniania mikrobiologicznego na większości złóż ropy naftowej na tym obszarze. Przekonującym dowodem są pozytywne technologiczne i ekonomiczne wyniki osiemdziesięciu miesięcy trwania projektu Pławowice. Wyniki testów laboratoryjnych symulujących proces mikrobiologicznego nawadniania złoża ropy przedstawiono wcześniej. Były one podstawą opracowania założeń projektu Mikrobiologicznego Nawadniania Złoża (MNZ) wdrożonego na złożu ropy naftowej Pławowice, który od samego początku miał na celu podniesienie wskaźnika sczerpania złoża, tzw. recovery factor. Projekt rozpoczęto we wrześniu 2011 roku, kiedy to na teren KRN Pławowice dostarczono, przygotowany w przemysłowym reaktorze INiG – PIB, biopreparat o wymaganych parametrach. Następnie na terenie kopalni uzyskano ciecz roboczą w ilości około 16 m^3 i zatłoczono do złoża

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odwiertem Pl-311, rozpoczynając w ten sposób projekt MNZ Pławowice, który trwa do dnia dzisiejszego. Prawidłowy dobór cieczy roboczej i technicznych warunków prowadzenia projektu zaowocował znaczącym przyrostem produkcji we wszystkich objętych projektem odwiertach. Produkcja w odwiertach Pl-52, Pl-159 i Pl-111 znacząco wzrosła – odpowiednio o 147%, 39% i 112% w porównaniu z produkcją sprzed rozpoczęcia projektu. Wdrożenie projektu nie wymagało żadnych nakładów inwestycyjnych na infrastrukturę czy personel KRN Pławowice, a w czasie całego okresu trwania projektu nie zanotowano żadnych problemów technicznych. W artykule pokazane zostały wyniki produkcyjne wybranych odwiertów oraz rezultaty analizy efektywności technologiczno-ekonomicznej projektu. Wyniki te są podstawą do rozważenia wdrożenia technologii MNZ na pozostałych jeszcze w eksploatacji złożach ropy naftowej Karpat i przedgórza Karpat.

Słowa kluczowe: MNZ, karpackie złoża ropy, dodatkowa produkcja ropy, krzywa spadku produkcji, nawadnianie mikrobiologiczne, MEOR

Introduction

It is estimated that almost 13 million tons of crude oil have been extracted from the Carpathian deposits during their entire exploitation period. In the absence of new discoveries it is necessary to use secondary and tertiary production methods appropriate to the given geological and economic conditions of the region in order to achieve the highest possible recovery of crude oil that still remains in place (Karnkowski, 1993; Pawlewicz, 2006; Stefaniuk and Tytko, 2014; Lubaś et al., 2016).

The Carpathian oil deposits have been depleted by years of primary and secondary exploitation. This considerably limits the scope of economically meaningful technologies that can increase production recovery factors such as frontal injection of water, gas, polymers or surfactants. Additionally, on small deposits where exploitation is carried out with just a few wells, it is not economically practical to implement technologies that require drilling new wells. It is therefore necessary to use existing marginal producing wells, wells that have been abandoned but not plugged, and wells with good well bore integrity that can be re-completed.

In special cases, after some small reconstruction and workover, these wells can be converted into injection wells. In addition, due to the lack of access to large amounts of water in the Carpathians, secondary oil recovery is primarily based on injection of reservoir water extracted with oil or gas. Like in other countries, produced water should not be treated as waste and disposed of using costly treatment and disposal methods (API, 1997; Falkowicz et al., 2012; Lubaś et al., 2016). Water is used in almost all processes of hydrocarbon deposit exploitation and the cost of its acquisition and subsequent treatment and disposal accounts for a large share of total production costs. Use of technologies and methods that require less water or that use re-injected produced water should be increased. An example is the microbial assisted waterflood project at Plawowice oil field.

Microbiological methods in oil industry

Bio-preparations have been used in the oil extraction, transport and storage industry for at least the past 50 years. For the purpose of this paper, bio-preparation means: *a microbial system comprised of microorganisms adapted to perform specific metabolic processes under reservoir conditions*. The bio-preparations used in hydrocarbon exploitation are typically prepared in a suspension of reservoir water or 3% ± NaCl solution. A prerequisite for the effective use of microbial assisted waterflood technology is the selection and evaluation of microbial compositions for their properties such as., transport through reservoir rock, and the ability to sustain growth in the reservoir. Therefore, it is important that the bio-preparation contain various strains with complimentary effects that fulfill these requirements.

Upstream benefits for the petroleum industry can be obtained by using bio-preparation for:

- oil well stimulation, single well 'bio-huff and puff';
- paraffin control, mitigation of plugging, near well bore clean up;
- microbial assisted waterflooding (MAW) – an MEOR method that can involve multiple injection and production wells or entire oil fields.

According to the most popular definition MEOR (Microbial Enhanced Oil Recovery) is a suite of methods and applications that utilize microbes or their bio-chemicals to increase the degree of depletion of an oil field in pursuit of economic benefits. MEOR is considered a tertiary method of oil field exploitation (Maure et al., 1999; Van Hamme et al., 2006; Lazar et al., 2007; Sen, 2008; Turkiewicz et al., 2009; Falkowicz et al., 2012, 2013). One of the better understood and most effective applications of MEOR technology is the Microbial Assisted Waterflood (MAW). Implementation of this technology at Plawowice began in September 2011 by injecting a large slug (16.5 m^3) of the prepared microbial system (MS) into the deposit at one time. This has been followed by periodic injections of produced water containing a small amount of beet molasses (2–4% w/w) augmented with mineral nutrients, i.e., phosphorus and nitrogen. The mechanisms by which biochemical processes work to increase oil recovery rates are complex and not fully understood (Maure et al., 1999; Falkowicz et al., 2012, 2013). However, it is known that the anaerobic digestion of molasses by the microbial composition used at Plawowice produces:

- gas: CO_2, CH_4, H_2 and others which reduce oil viscosity and can increase reservoir pressure;
- organic acids that increase the permeability of some reservoir rocks;
- surfactants (SPCs) and organic alcohols causing changes in wettability, lowering of interfacial tension (IFT) for oil-water, and positive changes in capillary pressures;
- bio-polymers and cell mass.

The production of bio-polymers and cell mass can partially plug the high-permeability zones (preferential pathways). After a period of time in the deposit, through the physical colonization of pore spaces, the microbial cell mass and resultant bio-polymers can cause a decrease in the local permeability of the deposit, thus a local redirection of water flow and ultimately influence the fluid flow dynamics of the entire reservoir. The injected water will begin to flow through fresh portions of the deposit through which it has not previously been flowing, or has been flowing to a small extent, thereby releasing additional amounts of oil still trapped in the reservoir. This is a very beneficial phenomenon from an economic point of view.

In addition, some of the fermentation processes are exothermic processes, which is very important in the case of shallow deposits where the deposit temperatures are low. All the processes described above can be synergistic, which makes the technology extremely efficient (Maure et al., 1999; Falkowicz et al. 2012). The great advantage of this technology is that once properly injected into the deposit the selected microorganisms have proven to be effective for a relatively long period of time, i.e., from six to eighteen months and longer. The cumulative effect of MAW treatment is an economically sustainable increase of the coefficient of depletion at every stage of the project.

Candidate reservoirs are screened for possible MAW treatment by comparison of their geophysical physical and geochemical properties within a set of application parameters. The selected microbial composition must be able to establish growth in the reservoir environment in which it will reside. Some of the major criteria are (Maure et al., 1999; Falkowicz et al., 2012):

- reservoir temperature range limits 10–85°C; microorganisms may quiesce in spore-forming state at the temperature of 10~25°C;
- optimal temperature range of 30–50°C; at this temperature, microorganisms are capable of doubling in number every 20 to 120 minutes;
- salinity of the reservoir water less than 15%; 3% NaCl solutions are typically used to prepare the microbial system to be injected;
- pH of the environment, optimum range 4–9;
- H_2S content in the aqueous phase should be less than 10 000 ppm[1];
- permeability 50–300 mD optimum;
- porosity 3 to 30%.

Premises for the application of microbial assisted waterflood technology in the Carpathians and Carpathian Foreland

The degree of depletion of geological resources in the Carpathians and Carpathian Foreland by primary methods, i.e., without using enhanced secondary and tertiary methods is small and ranges from 10% to 25% (Lubaś et al., 2016). Supporting methods of enhanced oil recovery (EOR) must be implemented. In the Carpathians, since the 1930s, secondary and third-order (tertiary) methods have been used, often with very good results. Currently, production from most Carpathian oil fields is carried out by pumping or applying inside-the-contour water flooding (Lubaś et al., 2008).

It is estimated that total extraction of oil from the Carpathian deposits currently exceeds 12 million metric tons. According to the literature, in the case of gravity regime, long-life production of oil field, and implemented secondary methods, the level of maximum recovery factor is about 0.4 or 40% (Lubaś, 2007; Lubaś et al., 2016). Based on these values, it is easy to calculate that in the Carpathian deposits approximately 18 million metric tons of oil remain subject to tertiary recovery methods. Increasing the recovery factor by about 5% would give approximately 1.5 million additional metric tons of oil. The presented estimates averaged all deposits and did not take into account the specificity and history of individual deposits. The quoted data, as indicators of resource depletion, provide a rationale for implementation of secondary and tertiary methods of exploitation of the Carpathian crude oil deposits. The relatively low cost method of Microbial Assisted Waterflooding (MAW) is a method that makes it possible to achieve a resource depletion ratio of 40% or perhaps even a few percent higher.

Technical scale experiments of microbial assisted oil recovery were conducted by the Polish Oil and Gas Institute from 1961–1971. The study involved eight Carpathian oil fields and sixteen oil wells. Their report concludes that the microbial method of crude oil release from the Carpathian deposits can be applied on an industrial scale. Their study further concludes

[1] The level of H_2S in the aqueous phase that will limit effectiveness of MAW has not been established. A limit of 10.000 ppm is suggested due to Health and Safety concerns rather than MAW performance.

using microbial methods to increase the coefficient of oil recovery has economic and environmental advantages over other EOR methods (Karaskiewicz et al., 1974).

Microbiological assisted waterflood project (MAW) for the Plawowice oil field

The Plawowice oil field was discovered in 1963 with the Pl-2 borehole. Reservoir rocks are upper Jurassic (raurak) limestones and sandstones and chalk conglomerates (cenoman) (Karnkowski, 1993). In the years 1978–1986, the field was waterflooded by injecting freshwater into two wells. The observed influence of the injected water on the reactive well allowed distinguishing the zone of increased permeability (the area of wells: 52, 53, 159). This fact, among others, determined the selection of the Pl-311 well as being injected in the microbiological waterflood project. The Pl-311 well is located at the top of the anticline, and the injected reservoir water travels along the bed bottom towards the Pl-52 and Pl-159 production wells, about 400 meters away (Fig. 1).

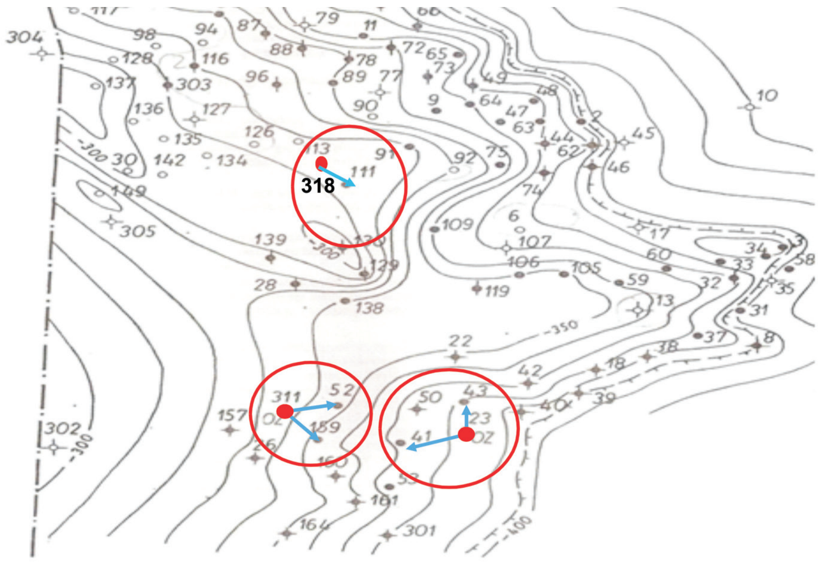

Fig. 1. Plawowice oil field
Rys. 1. Złoże Pławowice

The basic extraction and operational data (2010) of selected wells is given in Table 1.

After laboratory tests simulating the microbiological process of waterflooding the Plawowice deposit had been evaluated, a bio-preparation of RAM Biochemicals from USA was selected. Forty five kilograms (approximately 45 liters) of the bio-preparation was delivered to Krakow as a cryo-protected concentrate at a temperature of about –20°C. On September 2011, the 45 liters of bio-preparation was amplified to the volume of 1.5 m^3 by Polish Oil and Gas Institute – National Research Institute in an industrial reactor that provided anaerobic controlled thermobaric conditions for microbial growth using augmented beet molasses and simulated formation water brine. This step produced a sufficient volume liquid with proper cell count for the final step at the Plawowice oil field prior to injection.

In 27 September 2011 the bio-preparation was delivered to the Plawowice, where the treatment liquid was further amplified to approximately 16.5 m^3 and then injected into the deposit using the Pl-311 well, thus commencing Phase I of the MAW Plawowice project. In September 2014, a fresh round of bio-preparation was injected into the Pl-311, and Pl-318 added as an additional injection well (Phase II). This process was repeated in June 2017 (Phase III). The influence of the Pl-318 well on the Pl-111 well was established, and production data from all project wells was combined for the study. The best results, measured by production volume were obtained by the Pl-52 well (Fig. 2). The production volume is shown in Figure 2 for the period of 103 months, where the first 23 months show the monthly production history of the unassisted waterflood prior to MAW treatment in Phase I. It indicates a significant increase in production beginning in the sixth month of the project and continuing after the Phase II microbial system re-injection. It also indicates a projected trend line in red for production decline during the 23 month period before microbial treatment, predicting the exhaustion

Table 1. Selected production wells of the Plawowice deposit
Tabela 1. Wybrane odwierty produkcyjne złoża Pławowice

Production wells	Plawowice-52	Plawowice-159	Plawowice-111	Plawowice-41	Plawowice-43
Symbol	Pl-52	Pl-159	Pl-111	Pl-41	Pl-43
Temp. bottom hole [°C]	24	24	24	23	23
Press. bottom hole [MPa]	0.10	0.60	5.00	0.13	0.13
Production oil [mt/day]	2.3	1.8	0.3	4.4	0.6
Production water [mt/day]	0.05	0.20	0.80	0.30	0.40
Effective oil pay [m]	8.5	6.0	10.0	9.0	3.5

of the field during the study time frame, without microbial intervention. All oil above the red trend line in the decline curve analysis would be counted as incremental oil recovered, and calculated by integrating the area under the blue production curves above the red decline curve.

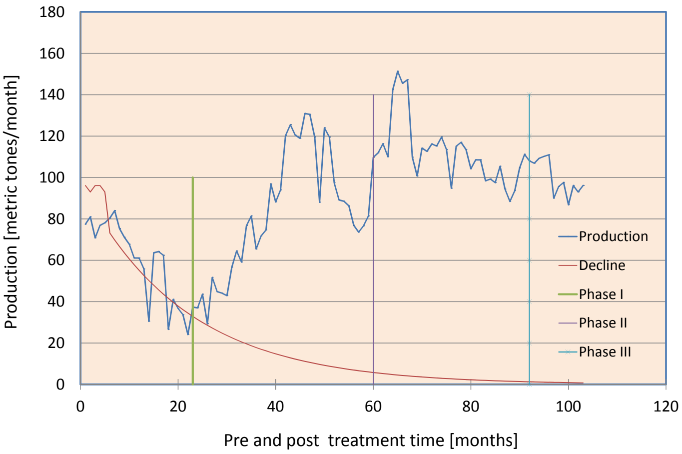

Fig. 2. The history of production of the Pl-52 well
Rys. 2. Historia produkcji odwiertu Pł-52

In a different approach to *incremental oil* that assumes a constant production from the pre-treatment unassisted waterflood and is denoted as *additional oil*, an average of pre-treatment production is calculated and used with production rate data to determine a % change for the whole study. On the basis of data on the monthly production volume Q_m from the wells of Pl-52, Pl-159 and Pl-311, the monthly average Q_{ave} production volume of the analyzed wells for the nine months before the project was calculated. The changes in the production of ΔQ [%] wells are calculated based on the formula:

$$\Delta Q\ [\%] = 100 \cdot (Q_m - Q_{ave})/Q_{ave} \qquad (1)$$

Production changes resulting in additional oil calculations are a basic indicator of the technological effectiveness of the MAW project on the Plawowice deposit and have been shown in the form of a graph in Figure 3.

Analyzing Figure 3, one can notice irregular changes in the ΔQ indicator to the seventh month of the project. Then, the index increases significantly, up to 255% in the case of the Pl-52 well in the 41st month of the project. In the case of the Pl-159 well, one can see some stabilization up to the 18th month and the maximum achieved (around 55%) in the 25th month of the project's duration.

It should be added that noticeable significant fluctuations (decreases) in production in the case of the Pl-52 well in the 26th month of the project were caused by submerged pump faults and after pump maintenance, the well production returned to its previous level. After the 28th month of the project, production of the Pl-52 well decreases to approx. 100% of

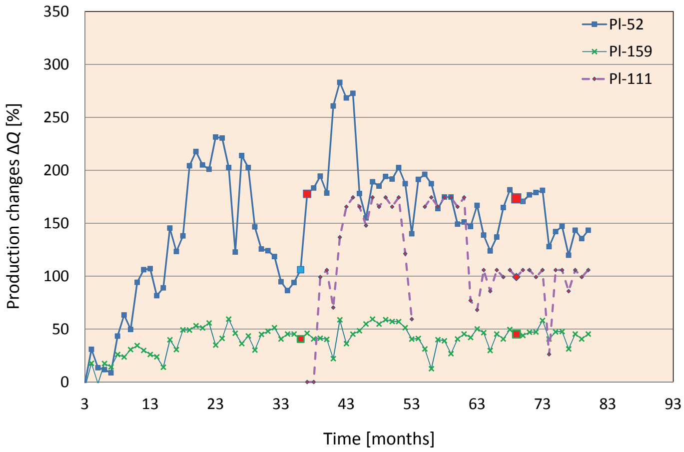

Fig. 3. Changes in the production of wells Pl-52, Pl-159 and Pl-111
Rys. 3. Zmiany w produkcji odwiertów Pł-52, Pł-159 i Pł-111

the output production. In the 36th month, the well had been subjected to mechanical bailing, which resulted in a return to high production from the period between 19 and 27 months of the project. At month 37, re-injection of microorganisms (as Phase II) into the deposit and high production at month 41 of the project can be interpreted as a positive result of this operation. From the 55th month of the project, a small but systematic drop in production to a level of around 150% of the initial production is noticeable. However, the production of the Pl-159 well from 18 to 80 months, fluctuating, remains at a level about 50% higher than the production before the start of the project. The Pl-111 well (introduced during Phase II) production increased and amounted to approx. 170% of the initial production, except for the decrease in month 53 caused by technical reasons. In the 69th month of the project, microorganisms were injected into wells Pl-311 and Pl-318 in an amount of approx. 4.5 m^3 in each, beginning Phase III. After three months in the Pl-52, Pl-159 wells there is a new trend of systematic production growth.

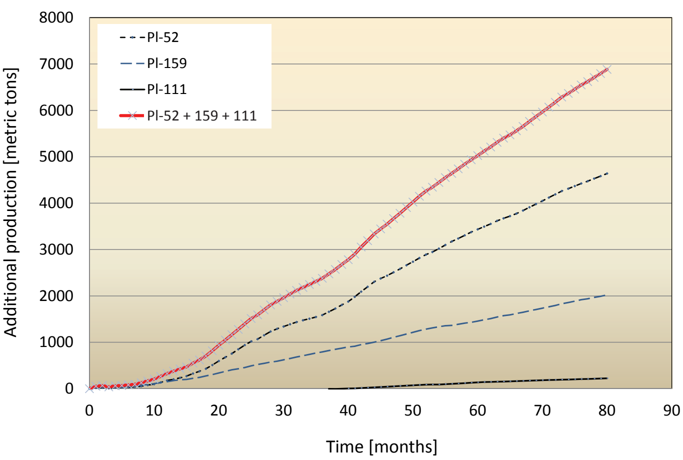

Fig. 4. Additional oil production in the MAW Plawowice project
Rys. 4. Dodatkowa produkcja ropy w projekcie mikrobiologicznego nawadniania złoża (MNZ) Pławowice

In total, after 80 months of the MAW Plawowice project, total crude oil surplus was obtained in the amount of approx. 6900 tons with a market value of approximately USD 4.3 million (Fig. 4). The result is that the cost of obtaining an extra barrel of oil is significantly lower than USD 10 per barrel.

Economic Efficiency & Analysis

Crude oil prices are not fixed, and Poland uses the oil it produces rather than exporting it. Consequently, the value placed on the additional oil produced (surplus oil) is its replacement cost based on market value. The terms *additional oil* and *incremental oil* are not used interchangeably in this paper as the calculations used are different for each. In this paper, additional oil (surplus oil) means *the amount of oil actually produced above the pre-MAW monthly average projected at a constant rate for the entire 80 month post-MAW period* (see above).

The calculations for additional oil recovered do not assume a decline curve and exhaustion of the field by non-MAW waterflood production; instead it looks at the percentage change in production using the average production rate from pre-MAW data and projects this rate monthly over the life of the project after MAW is implemented. This accumulation of additional oil is expressed as a percent change in production.

In turn incremental oil means *the total volume of oil actually recovered above the production decline curve. That is; the calculated volume of oil recovered that would not have been recovered had the MAW project not been implemented.*

The most widely utilized method for calculating incremental oil recovery is by the classical empirical equations which use decline curves established from prior non-MAW production data to determine the volume of potentially recoverable oil. This volume is subtracted graphically from the graph of actual production accumulated during the MAW project.

However, while the prior calculation methods provide a measure of project economy in terms of the value of additional or incremental oil produced per barrel or metric ton, and the amount of molasses required to produce each metric ton of additional or incremental oil, they do not give a full picture of the overall economic efficiency of the project. Therefore, further analysis is provided by using empirical Arp equations as explored by methodology of Fetkovich (Fetkovich et al., 1987; Landa-Marbán et al., 2017), in the form of Decline Curve Analysis (DCA) techniques that demonstrate an extension of the productive life of all project wells.

The pre-MAW production dQ_m/dt is projected to exhaustion ($dQ_m/dt = 0$), when plotted against Cumulative Production Q_{tot} and this green trend line equation is then used to determine life of production in months by solving for the integral of dt. Incremental oil is calculated by determining cumulative pre-Q_{tot} at exhaustion (Figure 5, green line x intercept of 5788 mt) and subtracting it from the total cumulative post-Q_{tot} for MAW project (18389 mt – 5788 mt = 12601 mt incremental oil). Then for the life of the project after initiating MAW, the production dQ_{maw}/dt is plotted until trend line production shows a new decline curve that can projected to a new Q_{tot} at $dQ_{maw}/dt = 0$, and a resulting new life of production calculated for the cumulative oil at exhaustion.

In this study, a new decline curve can be discerned after the pump failure and before Phase II re-treatment. When this second (blue) decline trend is extrapolated to exhaustion, the

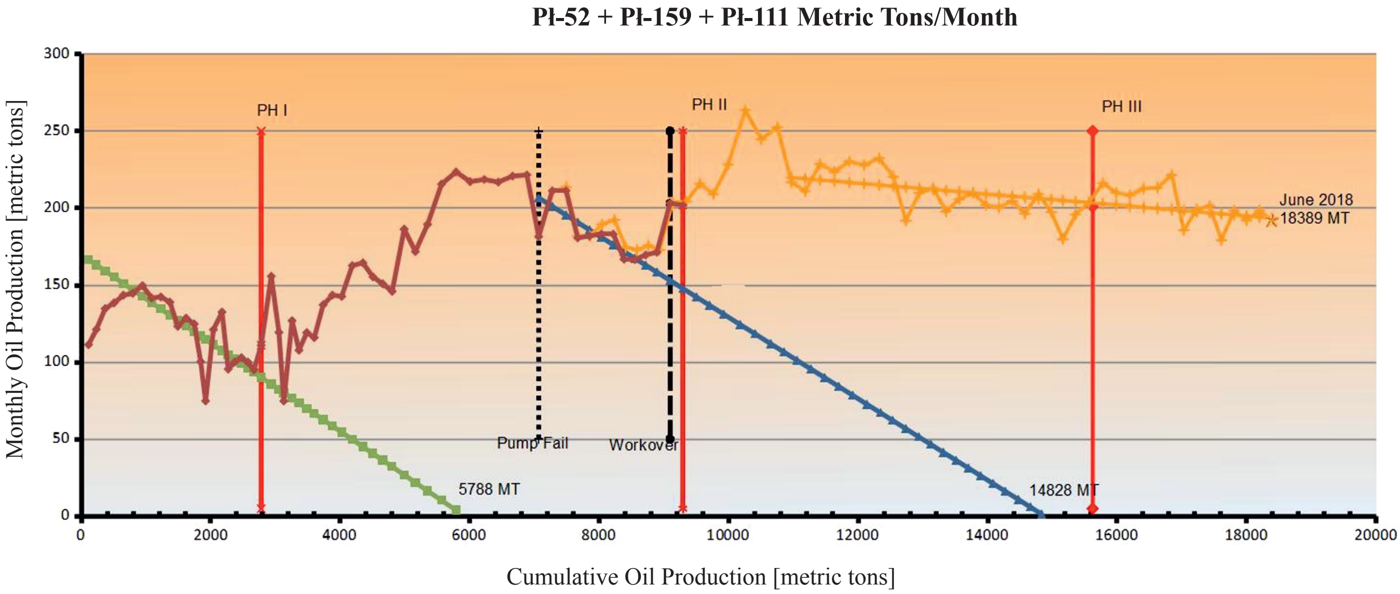

Fig. 5. Decline Curve of Cumulative Production Q vs Production dQ/dt

Rys. 5. Krzywa spadku produkcji Q w funkcji zmian produkcji w czasie dQ/dt

residual cumulative oil recovery is projected to exceed 14828 mt before the onset of Phase III with an incremental oil recovery of 9040 mt (156% over pre-Q_{tot} at exhaustion). Further examination of the Phase II and Phase III show a tentative orange decline curve which becomes apparent and has been in effect since the onset of Phase II through Phase III. It is indicative of a new threshold recovery rate that predicts a change in the recovery profile due to MAW techniques. This decline curve can tentatively be projected to extrapolate recovery to exhaustion at 320 months and reach 60500 metric tons of incremental oil in place, barring the need for interventions in the future. The extension in field productivity is evident in the incremental oil recovery predicted in these curves, but it is also evidence of well productivity life being extended. The long-term impact this extension in productive life has on the project's overall economic efficiency is manifest in break-even point projections and in return on investment calculations (ROI).

Summary

All three oil wells currently involved in the Plawowice MAW project, Pl-52, Pl-159 and Pl-111, show a significant increase in production (Fig. 3). The average value of these increments ΔQ is 147%, 39% and 112% respectively. *Additional oil* is calculated holding the average pre MAW monthly production as a constant and projecting it for the life of the project, than subtracting this total from the actual amount of oil produced. By July 2018 (80 months of continuous operations) total additional oil production had reached 6900± metric tons or approximately 53000 barrels.

Until the eightieth month of the project, approximately 405 metric tons of beet molasses were injected into the deposit, which gives an indicator of 0.059± metric tons molasses for each additional ton of crude oil produced. The average price of molasses along with transport to Plawowice oil field was about 145 USD/metric ton, so in the analyzed period the cost of molasses is about 8.5 USD for each metric ton of additional oil (1.18 USD/bbl). Cost of supplement, nitrogenous fertilizer, is negligible. Higher recovery factors are anticipated to continue for many months and this will have a positive economic impact on the overall project cost by increasing the total additional oil produced, thereby lowering the unit cost of paid fixed expenses and recurring costs (molasses, supplements, labor and lifting costs).

In addition, an improvement in the injectivity of the Pl-311 injection well was observed, which is manifest by shorter injection times for the same volume of water to be dispersed into the bed. This improvement is likely caused by organic acids produced by microbes that have subsequently colonized in the vicinity of the well. This can translate into reduced lifting and production costs per metric ton, and it is one aspect of savings that should be investigated in future economic evaluations. However, for the purposes of this study, all lifting costs were assumed to remain a constant commensurate with unassisted waterflooding. It should also be noted that no interventions have been required for the Pl-311 injector in seven years, or the Pl-318 injector in four years since its initial microbial treatment in 2015.

Based on the results of Plawowice MAW project, the following conclusions can be drawn:

1. MAW technology is capable of producing sustained increases in oil recovery rates.
2. Only small modifications to the existing waterflood system were required to implement the MAW project at Plawowice.
3. The productive life of all project wells has been extended as has their economic Break-Even Point (B-E).
4. Return on Investment is expected to increase with prolonged higher recovery rates.
5. This technology has proven to be cost effective when implemented at small scale, and capable of being increased to industrial scale.
6. MAW is particularly suited for Carpathian carbonate oil reservoirs where some EOR technologies cannot be applied efficiently.
7. This process is economically attractive for marginally producing oil fields in the Carpathian geologic system, and should be investigated as an alternative to abandonment.

The authors of the article recommend continuation of the MAW Plawowice project, as well as investigating the use of microbiological assisted waterflooding at other suitable oil fields in the Carpathians and the Carpathian Foreland.

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