Cultivation of industrial hemp accelerating reclamation of land degraded by open mining of lignite

Jerzy MAŃKOWSKI*, Jacek KOŁODZIEJ, Andrzej KUBACKI, Przemysław BARANIECKI, Irena PNIEWSKA – Institute of Natural Fibres & Medicinal Plants, Poznań, Poland; Krzysztof PUDEŁKO – Department of Biochemistry and Biotechnology, Faculty of Agronomy and Bioengineering, Poznań University of Life Sciences, Poznań, Poland

Please cite as: CHEMIK 2014, **68**, 11, 983–988

Introduction

Before the lignite can be excavated by the open-mining method, the land has to be dried. Having done that, the top layer over the lignite deposit – so called overburden – has to be removed together with all the vegetation and the soil. This layer is usually several tens of meters thick. In case of 6 m thick lignite deposit in Kazimierz Biskupi, the thickness of overburden to be removed was 47 m. When all the lignite is excavated, a dead excavation pit is left which must be filled. During removal of the overburden the soil layers are misplaced and mixed, therefore the filled excavation pit is characterized by only traces of humus, if any at all. Practically, the structure formed after the pit is filled cannot be called a soil as the soil is a biologically active layer containing mineral, organic and organic-mineral particles.

Picture 1. Area before remediation

There are three main directions of degraded land reclamation: for agriculture, forestry and special one. Currently, agricultural reclamation of degraded land is carried out by growing limited number of crops, which are then used for energy, food and feed [Chwastek J. et al. 1998, Karczewska A. 2008]. The methods of agricultural reclamation used so far did not bring satisfactory results, as the soils in which the process of humus formation has only began are used instantly for production resulting usually very low yields. Soil devastated by the open mining has a disturbed geomechanical composition and is deficient in some essential nutrients which makes it not suitable for the production of food and fodder crops. Such crops are subject to diseases and pests and do not represent valuable food for humans and animals.

Corresponding author:
Jerzy MAŃKOWSKI, Ph. D., Eng., Assoc. Prof., e-mail: jerzy.mankowski@iwnirz.pl

The effectiveness of reclamation methods used for post-mining land is limited. Reclamation without intensified agronomic treatments takes tens of years. Combination of two crops in crop rotation: hemp (producing big amounts of biomass) and alfalfa (able of fixing nitrogen from atmosphere thanks to symbiosis with Rhizobium bacteria) will considerably accelerate the process of humus layer formation in reclaimed soil. It is also important that both crops form well-developed root system that aerates the soil and improves the air-water conditions. Combination of these two crops creates a form of biological composite that stimulates the processes of humus formation and increases the fertility of the soil.

The process of soil formation takes a long time. An important form of organic matter in the soil is humus. Supplying big amounts of organic matter to the soil by ploughing down the cultivated crops at the depth of 20 and 30 cm will accelerate this process. Plant material mixed with the soil will create a biological scaffold for developing soil flora and fauna.

Selection of plants used in agronomic reclamation

Comparing to other crops, hemp grows very fast. The maximum daily growth rate of plants is reached in the full blooming stage while the maximum height at the end of flowering. Hemp produces as much as 12 t of biomass per hectare and forms a deep, tap root system that reaches 1.0-1.5 m into the soil. Hemp stems are 3-4 m tall. They do not brake due to the presence of long and strong cellulosic fibres in the stem creating a strong, stiff structure. The content of cellulose and cellulose-like substances in the dry matter of hemp is 70-75% [Cierpucha W. et. al. 2013]. All the qualities of hemp mentioned above enable it to contribute to quick reconstruction of humus layer. Additionally, a well-developed root system of plants will form a vertical channels enhancing the aeration of the soil. The roots of alfalfa cultivated after hemp will grow through the ploughed down hemp plants that undergo a gradual humification. This will intensify the growth of soil microorganisms that have a substantial effect on formation of humus.

Picture 2. Hemp grown on reclaimed land

Research results

Before agronomic treatments could be conducted in selected experimental fields, they had to be cleared of volunteer vegetation of weeds and bushes as well as stones. The number of stones made the work in the field impossible.

Table 1

Soil parameters before the remediation process

Field	pH	P2O5 mg/100g	K2O mg/100g	Mg mg/100g	B mg/1000g	MN mg/1000g	CU mg/1000g	ZN mg/1000g	FE mg/1000g
I	7,9	2,2	11,1	7,9	0,85	153	4,3	6,7	1423
	7,9	2,3	13,3	10,2	1,25	134	4,7	7,5	1301
II	8,0	2,4	12,6	8,3	1,43	138	4,0	6,7	1319
	8,1	2,9	9,9	7,0	0,68	109	2,9	5,2	1106

Phosphorus in the soil was determined by spectrophotometric method, potassium by flame photometry and magnesium by atomic absorption spectrometry. The soil pH was determined in 1N KCl. Micronutrients, such as manganese, zinc and copper were determined by atomic absorption spectrometry while boron by spectrophotometry.

Before sowing, the field was disc-harrowed, then ploughed, followed by pre-sowing tillage and application of lime and next nitrogen, phosphorus and potassium. Application of lime improved uptake of other mineral fertilizers by the plants. Than the hemp and alfalfa were sown.

In October the hemp was mowed by the tractor-hooked mower. The mower is furnished with three knives that cut the hemp stems in three places. This facilitated ploughing the plant biomass down. The average yields of biomass are presented in Table 2. To accelerate the decomposition of biomass, the biological preparation accelerating the degradation of post-harvest biomass was applied.

Table 2

Average yields of biomass obtained in reclaimed land

	Field 1	Field 2
Average yields of biomass [kg/ha]	Hemp in 2013	
	1 818	2 511
	Hemp in 2014	
	1 593	2 273

Each year the Project is conducted, the soil is analysed to show the progress in reclamation process. The soil in field I has basic reaction, shows high content of magnesium as well as average and low content of potassium and phosphorus. Similarly, the soil in the field II has basic reaction and is characterized by average content of magnesium and low content of potassium. The content of phosphorus is very low [Mańkowski J. et. al.].

Both fields show low content of boron and average content of manganese, copper, zinc and iron. Comparison of humus content in experimental fields, in two first years of the Project is presented in Table 3.

Table 3

Content of humus in the soil in two first year of reclamation process

Filed	Test	Humus level [%] January 2013 (before remediation)	Humus level [%] January 2014	Change in humus level in 2013 – 2014 [%]
I	1	1.30	1.91	31
	2	1.51	2.16	30
II	1	1.48	1.77	16
	2	0.76	0.98	22

Spectrometric analysis shows that both sites differed significantly in terms of the content of humus substances. Soil in the field I contained almost three times more humus acids as compared to the field II. However, this higher content is less than 50% of humus compounds in cultivated soils.

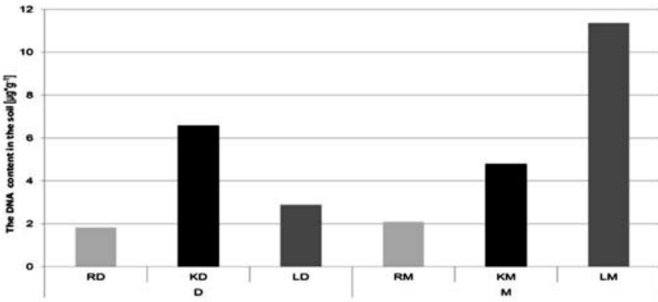

Fig. 1. The DNA content in the soil depending on the site and grown crop D – field II, M – field I, RD, RM – control on the site, K – hemp on the site, L – alfalfa on the site

In both fields (field I and field II), the DNA content in the control samples was very low (approx. 2 mg per gram of soil). In the field II in objects where hemp was grown, the DNA content was over three times higher than in controls, despite a lower content of humic substances and also more than twice as high as in the objects where alfalfa was grown. A slightly different situation was observed at the field I, where alfalfa grew better than in the field D. Higher DNA content can be linked in this case with the well-known stimulating effect of legumes on certain groups of soil bacteria, in particular Rhizobium and Bradyrhizobium. In this filed in the object where hemp was grown, two times less DNA was obtained from the soil than in objects with alfalfa, but still twice as much as in the fallow control objects.

Resume

In the first year of reclamation process, a number of agronomic treatments was carried out that have contributed to the improvement of agricultural conditions on the reclaimed area. The methodology of the work, involving the cultivation of hemp and alfalfa and ploughing down the obtained biomass, has improved the level of humus in reclaimed land. In the first year of the project the level of humus increased by approximately 20-30%.

After reclamation process is completed, the hemp grown the reclaimed land can be used for technical applications like for fibre used in composite materials, nonwoven for construction industry and for paper production. Hurds, which are a by-product from fibre extraction process, can be used as a renewable source of energy. The calorific value of hemp hurds is over 18 MJ/kg [Kołodziej J. 2009, Mańkowski J. et. al. 2014]. Hurds are very promising feedstock for construction industry. In combination with lime, they can be used for insulating elements filling the walls, for plasters and floors [Bevan R. et. al. 2008]. The Project constitutes a model system illustrating new method for reclamation of post-mining land by cultivation of hemp and which subsequently can be used as renewable feedstock.

Literature

1. Bevan R., Woolley T.: Hemp lime construction. BrePress 2008.
2. Cierpucha W. et. al.: Technologia uprawy i przetwórstwa konopi włóknistych. IWNiRZ 2013, str. 111-117.
3. Chwastek J., Janusz W., Mikołajczak J.: Przyrodnicze wartości odkrywkowych wyrobisk górniczych. Mat. Konf. Technologiczne, przyrodnicze i gospodarcze uwarunkowania eksploatacji i zagospodarowania wyrobisk skalnym. Górn. Odkr. 40, 1998, str. 3.

4. Karczewska A.: Ochrona gleb i rekultywacja terenów zdegradowanych. Wydawnictwo Uniwersytetu Przyrodniczego we Wrocławiu, 2008, str. 202-2014.
5. Kołodziej J.: Efektywność energetyczna konopi w zależności od czynników agrotechnicznych. Praca doktorska, Uniwersytet Przyrodniczy w Poznaniu: 2009, str. 84-96.
6. Mańkowski J., Kubacki A., Kołodziej J., Baraniecki P., Pniewska I.: Tereny pokopalniane – drugi rok rekultywacji. Biuletyn Informacyjny PILiK Len i konopie nr 23, 2014, str. 4-7.
7. Mańkowski J., Kołodziej J., Baraniecki P.: Energetyczne wykorzystanie biomasy z konopi uprawianych na terenach zrekultywowanych. Chemik Nauka, technika, rynek 10. 2014, str. 901-902.

*Jerzy MAŃKOWSKI – Ph.D., Eng., Professor of INF&MP, graduated from the University of Agriculture as M.Sc. in Agricultural Chemistry in 1983; holding the Ph.D. degree in Agricultural Sciences in 1998. The doctoral thesis are entitled: „The Influence of Nitrogen Fertilization, Density of Sowing and the Date of Harvesting of Fiber Flax on the Quantity and Quality of the One-Type Fibre, as a Raw Material for Blended Yarns.

He works as the researcher at the Institute of Natural Fibres and Medicinal Plants from 1983.

He is involved in research in following fields: technology of flax and hemp harvest on the plantation; extraction and processing of flax and hemp fibre; methods of improving the quality of flax and hemp fibres to be applied in the blends with another natural fibres; application of bast plants and derivative products in different industrial branches.

Jacek KOŁODZIEJ – Ph.D., Eng. Academic studies and employment history: since 2003 Researcher at Institute of Natural Fibres and Medicinal Plants. In 2009 he got his Ph.D. in Agricultural Sciences at Poznań University of Life Sciences. Carries out research in the field of agricultural technology and fiber plants processing as well as use of whole plants, straw, and waste processing flax and hemp for energy.

Krzysztof PUDEŁKO – Assistant professor at the Department of Biochemistry and Biotechnology, Poznan University of Life Sciences – lecturer of biochemistry, molecular biology and environmental biochemistry. His research interests cover microbiological and biochemical aspects of agricultural production, with particular emphasis interactions in the environment based on the phytotoxic activity of substances of plant origin and the impact of cropping systems on soil environment. He is also interested in biotechnology of composting processes and biological nitrogen fixation. He is experienced in creating and developing research cooperations with industrial partners after 12 years activity as R&D manager and as research consultant. He has developed and implemented the number of processes and technologies in the field of bioconversion of agricultural products.

Andrzej KUBACKI – Ph.D., Eng., graduated from University of Agriculture and Technology in Olsztyn with the title of engineer (1978). In 2001 he defended his M.Sc. thesis at the Agricultural University of August Cieszkowski in Poznan. He got his Ph.D. in agricultural sciences in 2011 at Poznan University of Life Sciences. He works as the Director of the Processing Plant LENKON in Stęszew (INF&MP). He specializes in issues related to the collection and processing of flax and hemp straw, pre-production and processing of fiber.

Irena PNIEWSKA – M.Sc., graduated from the Adam Mickiewicz University in Poznan. For many years, she works at the Department of Scientific Information and International Cooperation at the Institute of Natural Fibres and Medicinal Plants in Poznan. From 2012 she is a coordinator regarding disseminating the results accomplished at the INF&MP within the Project: Life 11/445 / EN – Remediation of degraded land in the region of Konin Lignite Mine to cultivation of industrial hemp.

Nagrody Fundacji na rzecz Nauki Polskiej 2014

Fundacja na rzecz Nauki Polskiej po raz 23. przyznała Nagrody Fundacji, które cieszą się opinią najważniejszego wyróżnienia naukowego w Polsce. Laureatami zostało czterech wybitnych polskich uczonych – prof. Tomasz Goslar, prof. Karol Grela, prof. Iwo Białynicki – Birula oraz prof. Lech Szczucki.

Nagrody Fundacji są przyznawane za szczególne osiągnięcia i odkrycia naukowe, które przesuwają granice poznania i otwierają nowe perspektywy, wnoszą wybitny wkład w postęp cywilizacyjny i kulturowy naszego kraju oraz zapewniają Polsce znaczące miejsce w podejmowaniu najbardziej ambitnych wyzwań współczesnego świata. Wysokość nagrody wynosi 200 tys. PLN.

Prof. Tomasz Goslar z Uniwersytetu im. Adama Mickiewicza w Poznaniu otrzymał Nagrodę Fundacji na rzecz Nauki Polskiej 2014 w obszarze nauk o życiu i o Ziemi – za kluczowy dla współczesnych badań klimatycznych wkład w ustalenie chronologii zmian stężenia izotopu węgla C14 w atmosferze podczas ostatniego zlodowacenia.

Prof. Karol Grela z Uniwersytetu Warszawskiego i Instytutu Chemii Organicznej PAN w Warszawie otrzymał Nagrodę Fundacji na rzecz Nauki Polskiej 2014 w obszarze nauk chemicznych i o materiałach – za opracowanie nowych katalizatorów reakcji metatezy olefin i ich zastosowanie w praktyce przemysłowej.

Prof. Iwo Białynicki – Birula z Centrum Fizyki Teoretycznej PAN otrzymał Nagrodę Fundacji na rzecz Nauki Polskiej 2014 w obszarze nauk matematyczno-fizycznych i inżynierskich – za fundamentalne prace dotyczące pola elektromagnetycznego, które doprowadziły do sformułowania zasady nieoznaczoności dla fotonu.

Prof. Lech Szczucki z Instytutu Filozofii i Socjologii PAN otrzymał Nagrodę Fundacji na rzecz Nauki Polskiej 2014 w obszarze nauk humanistycznych i społecznych za wyjaśnienie związków kulturowych Europy Środkowej i Zachodniej w monumentalnej edycji korespondencji Andrzeja Dudycza, XVI-wiecznego myśliciela, reformatora religijnego i dyplomaty.

Kandydatów do Nagrody FNP, zgodnie z jej regulaminem, zgłaszać mogą wybitni przedstawiciele nauki zaproszeni imiennie przez Zarząd i Radę Fundacji. Rolę Kapituły konkursu pełni Rada Fundacji, która dokonuje wyboru laureatów na podstawie opinii niezależnych recenzentów i ekspertów oceniających dorobek kandydatów. W skład Rady w obecnej kadencji wchodzą profesorowie: Andrzej Jerzmanowski (Wydział Biologii UW i Instytut Biochemii i Biofizyki PAN) – przewodniczący Rady, Irena E. Kotowska (Instytut Statystki i Demografii SGH) – wiceprzewodnicząca Rady, Leon Gradoń (Wydział Inżynierii Chemicznej i Procesowej Politechniki Warszawskiej), Henryk Koroniak (Wydział Chemii UAM), Marek Świtoński (Katedra Genetyki i Podstaw Hodowli Zwierząt Uniwersytetu Przyrodniczego w Poznaniu), Wojciech Tygielski (Instytut Historii Sztuki, Wydział Historyczny UW), Karol I. Wysokiński (Zakład Teorii Fazy Skondensowanej UMCS). Nagrody są przyznawane w czterech obszarach: nauk o życiu i o Ziemi, nauk chemicznych i o materiałach, nauk matematyczno-fizycznych i inżynierskich oraz nauk humanistycznych i społecznych.

Uroczystość wręczenia nagród odbędzie się 3 grudnia br. na Zamku Królewskim w Warszawie. (*em*)

(http://www.fnp.org.pl/nagrody-fundacji-na-rzecz-nauki-polskiej-przyznane/, 31.10.2014 r.)