Valuable Deposits of Sand and Gravel in the Valleys of Carpathian Rivers (Poland) VS Protected Areas

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Summary

This paper is a description of the dynamics of sand and gravel mining in the Polish Carpathians. Environmental limitations imposed on sand and gravel mining within Natura 2000 areas and other forms of nature and landscape conservation impede mining activity in those areas. The Natura 2000 network is in conflict with the industry, especially with opencast minEng. Many protected areas have been established within managed and unmanaged deposits of sand and gravel. This may potentially pose the threat of abandoning extraction.
In order for mining not to be perceived as an adverse factor, but as an activity which introduces a new quality, former mining sites should be properly reclaimed. Many decommissioned opencast mines undergo reclamation with respect to biodiversity. If mining is performed in an already impoverished natural environment, the established areas may become a habitat for wild species or even form ecological corridors between the priority protected areas. This contributes to increasing the cohesion of the network of Natura 2000 areas. Former mining sites of minerals have favorable habitat conditions for the roe deer, deer. They become nesting grounds for falcons, pheasants, linnets, and night herons.
With public consultations and targeted efforts, degraded sites may become habitats for many species of animals, plants and mushrooms. Should reclamation be abandoned, negative changes may take place: erosion, surface mass movements, changes in ecosystems, eutrophisation of waterbodies, etc. Development of natural aggregates extraction is a chance for Poland's economic growth. It must, however, proceed in harmony with the environment.

Keywords: mining, deposits of sand and gravel (natural aggregates), environmental protection, nature conservation, Natura 2000

Introduction

Rapid economic development has lead to intensified mining works in Poland and all over the world. Even a few dozen years ago, the profits generated through mining were a priority issue, while very little attention was given to the effects of that activity. Degraded areas were left for nature to heal them. As the area of devastated patches of land expanded, the society began to perceive mining as a major threat to the environment (Klojzy-Kaczmarczyk, 2013; Stala-Szlugaj,2013). Despite wide-ranging reclamation projects, the effects of past negligence can still be found.

It is possible to improve the image by proper reclamation adapted to the needs of local communities (Badera, 2010; Sobczyk andKowalska, 2013).

Mining may bring a number of benefits provided that extraction is properly performed and provided that reclamation – implemented with a creative approach – introduces new quality.

All EU Member States implement their economic programs following the concept of sustainable development. In Poland, construction and road industries rely heavily on natural aggregates. Abandoning or reducing the scope of mining would inevitably increase prices and lead to greater illegal extraction. By attempting to protect the environment, we may unintentionally harm it. This is so because illegal extraction of aggregates from riverbeds or shallow deposits may pose a threat not only to fauna and flora but also to the deposits themselves as they are a component of the environment.

Mining of natural aggregates depends on many intertwined factors. Among them a crucial role is played by social factors, namely ethics and environmental awareness of the people engaged in mining as well as of local communities. The factors are reflected in the way the environment, being a source of economic, health-related, recreational and aesthetic profits, is taken care of.

Many deposits of minerals that provide strategic raw materials, crucial for Poland's economic development, are located within valuable natural areas. These deposits are unevenly scattered across the country, just as Natura 2000 areas are. There are approx. 300 deposits of natural aggregates in Poland located within Natura 2000 areas, of which 1/3 is commercially utilized. The remaining deposits are managed in the following way: 41 are temporarily active, 64 are unmanaged with resources having been comprehensively recognized, 28 have been preliminarily recognized, and 64 are deposits where mining activity has been abandoned. The network areas with deposits amount to 15% - 40% of all the areas established in a given province (Pietrzyk-Sokulska, 2009).

Origins Of Aggregates And Division Thereof

In 2006, the term sand and gravel was replaced with the name natural aggregates(Łochańska, 2010). In scientific papers both terms are still used. Sand is a loose sedimentary rock made of non-bonded mineral grains, quartz primarily. The grain sizevaries from 0.0625 mm to 2 mm, and the density of quartz sand-grainsis about 2.62g/cm^3.Sand is the most frequent loose sedimentary rock. Sand deposits can be found in the whole of Poland. Gravel is sedimentary rockd-ebris that is loose inform and composed of a variety of rock sand mineral swith a diameter greater than 2 mm (up to several centimeters). In the construction industry gravel is understood as anatural aggregate up to 63 mm in fraction. Deposits of sand and gravel differ in size, mineral accumulation, quality, the thickness of the overburden, while their common feature is their stability (in situ).

Sand and gravel (natural aggregates) are statutorily classified as common minerals. It is a loose mixture of clastic material composed of pebbles, gravel and sand (Glapa andKorzeniowski, 2005). In Poland, deposits of natural aggregates occur in 98% in Quaternary deposits (Ney, 2003, Miziołek, 2007). There are five genetic types of aggregates:

- glacial, formed as a result of meltwateractivity within theglacieranditsmarginal zone; they occur mainlyin the northernand central parts of Poland;
- fluvioglacial, formed byoutwashconedeposit-sandin glacial valleysin the glacier foreland; they occur in northernand central Poland;
- aeolian, formedfrom a materialcarried by thewind; they occur on the surfaceof fluvioglacial or riversediments;
- marine or offshore sand and gravel deposits, resulting mainly from the wash of older deposit sand their redeposition by sea currents; they occur at the bottom ofthe Polish economic zoneof the Baltic Sea;
- alluvial, formed bythe accumulation of alluvium, at terrace sand alluvial cones; they occur mainly in the southern part of the country in the Carpathian-Sudeten area. In the Sudeten part, deposits of sand-gravel are dominant, while in the Carpathian area – deposits of gravel and sand - gravel (Górecki and Seremet, 2009; Kowalska, 2010; Miziołek, 2007).

In Poland, the most numerous are glacial deposits with small resources. Alluvial deposits have the greatest resources, i.e. more than a half of all of them. The origin of deposits is strictly linked to the size of resources, qualitative features of minerals and diversification of the inner structure of a given deposit.

Natural boundaries of deposits are designated by zones of lithological changes; however, for the purpose of mining, artificial boundaries are usually established on the basis of characteristics of an area or based on boundaries of protected areas (Jurys, 2009). This results in excessive fragmentation of deposits in key deposit areas. Mining of small, fragmented deposits contributes to their irrational utilization. Other factors used to establish boundaries of deposits include the degree of area management and protection-related requirements set for landscape, groundwater and soils.

Aggregates are divided with respect to sand content, i.e. percentage share of the mass of 0.063 mm – 2.0 mm particles. Depending on the sand content aggregates can be divided into four groups:

- gravel aggregate – sand content 0-30%
- gravel-sand aggregate – s.c. 30-50%
- sand-gravel aggregate – s.c. 50-75%
- sand – s.c. 75-100% (Glapa and Korzeniowski, 2005).

Resources Of Natural Aggregates In Poland

The deposits of natural aggregates in Poland are unevenly distributed, so mining is performed mainly in four areas: northern, central, south-western and south-eastern (Table 1).

Industrial economic resources are estimated at 2.3 billion tones.Their largest part can be found in deposits already being managed. Most anticipated economic resources can be found in the following provinces: Dolnośląskie, Małopolskie and Opolskie.

In 2011, 8,628 deposits were registered, of which 2562 were mined (including 882 – only periodically). The category of unmanaged deposits is dominated by comprehensively recognized deposits (3012), while 340 deposits were preliminarily recognized. Mining of 1898 deposits was abandoned for various reasons.

Dynamics of natural aggregate mining in Poland

For over 20 years the size of recognized resources and extraction of natural aggregates have been on the rise. In 1990, mining of sand and gravel amounted to a little over 60 million tonnes, while in 2011 – almost 250 million tonnes. The lowest results of mining were recorded in 1991 (low demand resulting from political changes), while the highest – in 2011. Resources of sand and gravel in 1990 amounted to 12.4 billion tonnes, while in 2011 –17.2 billion tonnes. According to the UNCF classification,extractable resources of sand and gravel aggregates amount to 1.6 billion tonnes, while the remaining resources –1.8 billion tonnes.

The current annual extraction level is estimated at 150 million tonnes. It should be noted, however, that

Tab 1. Regions where deposits of natural sand-gravel aggregates can be found in Poland (Radwanek-Bąk, 2010)

Tab. 1 Potencjalne lokalizacje złóż kruszyw naturalnych, piasku i żwiru w Polsce (Radwanek - Bąk , 2010)

Region	Location by administrative division (provinces)	Resources in deposits
northern	Zachodniopomorskie, Pomorskie, Warmińsko-mazurskie, Kujawsko-pomorskie, Mazowieckie (exl. southern part), northern part of Lubuskie (districts: Gorzów, Międzyrzecz, Świebodzin, Sulęcin, Słubice, Strzelce), northern part of Wielkopolskie Province (districts: NowyTomyśl, Szamotuły, Międzychód, Grodzisk, Września, Śrem, Gniezno, Piła, Złotów, Czarnków, Chodzież, Wągrowiec, Poznań), Podlaskie	large:>10 Mt average:10-1.5 Mt small:< 1.5 Mt
central	Łódzkie, southern part of Wielkopolskie, southern part of Mazowieckie (districts: Radom, Kozienice, Szydłowiec, Przysucha, Zwoleń), Świętokrzyskie, Lubelskie	large:>15 Mt average:10-5 Mt small:< 5 Mt
south-western	Dolnośląskie, Opolskie, Śląskie (excl. south-eastern part), southern part of Lubuskie	large:>10 Mt average:10-1,5 Mt small:< 1,5 Mt
south-eastern	Małopolskie, Podkarpackie, southeastern part of Śląskie (districts: Bielsko-Biała, Żywiec, Cieszyn)	large:>10 Mt average:10-1 Mt small:< 1 Mt

the real extraction is, in fact, several percent higher as a result of illegal extraction of natural aggregates, especially during the construction of roads and large structures. According to the data above, the extractable resources of aggregates will last for another 10.5 years only (Ney, 2008). The simulation does not take into account the deposits of currently unmanaged minerals. In their case, the resource reserve ratio (which determines the minerals supply in the future) is rather average, namely 40-60% (Kasztelewicz, 2011). According to the calculations by Radwanek-Bąk(Radwanek-Bąk, 2010), extractable resources will last for 9.9 years, with the reserve ratio of 43.9%.

The provinces of Mazowieckie, Wielkopolskie, Śląskie, Dolnośląskie, Małopolskie, Pomorskie and Łódzkie have recorded a growing demand for natural aggregates. Shortages of aggregates on local markets are often compensated for by deliveries from remote regions of Poland despite higher prices generated by transport. The largest deficit of aggregates is recorded in the following provinces: Małopolskie, Warmińsko-mazurskie, Podlaskie, Opolskie and Zachodniopomorskie(Galos, 2012).

Over 3.5 billion tonnes of aggregates are mined in the EU every year. The biggest producers are: Germany (470 million t/year), Spain (430 million t/year), France (approx. 400 million t/year), Italy (350 million t/year), Great Britain (200 million t/year). In Poland, aggregate production is approx. 5.5 t/capita, while in the EU Member States – 7 t/capita on average (Czaja and Kozioł, 2010).

Utilization of aggregates

Natural aggregates, containing fractions from 0.1 mm to several dozen millimeters, are mainly used in residential and industrial construction, comprising 75% of concrete mass. They are a valuable raw material in road industry, where they comprise 90% of road structure mass (Bąk et al., 2009;Góralczyk, 2004). Currently aggregates are utilized that have the same qualities and functions as natural aggregates, but come from other sources. These are aggregates generated by the power industry and metallurgy, as well as some fractions of crushed aggregates. Since aggregates are mined at a small depth, the costs of extraction are not high. Transport charges, however, significantly affect the price of raw materials. For extraction to be feasible in the economic sense, it must be performed in the areas where the demand for a given raw material is the highest: according to estimates up to 20 km from the mining site.

Mining Of Sand And Gravel In The Carpathians

In the area of the Polish Carpathians and Carpathian foothills, over 17% of documented domestic resources of natural aggregate can be found. Gravel deposits are dominant, with less than 30% sand fractions, while among finer aggregates the content of sand fraction does not exceed 50%. In almost every case the mineral is of alluvial origin. The documented deposits can be found within rivers: upper Vistula, Soła, Skawa, Raba, Dunajec, Biała, Wisłoka, San, Jasiołka and Ropa in Holocene or Holocene-Pleistocene alluvial terraces (Radwanek-Bąk, 2010).

Over 75% of all documented Carpathian deposits can be found in the Dunajec River Valley. In the valley of the Wisłoka River, 45 deposits were recorded (Photo 1). The analysis of the way the Carpathian resources of sand and gravel are managed leads to a conclusion that within managed deposits there are 6% of documented resources, while 86% are reserve deposits. The remaining 8% are abandoned deposits.

The deposits vary significantly in terms of thickness – from 2-6 m in the mountain sections of river valleys to 6-8 m in central and lower sections. Overburden thickness varies from several dozen centimeters up to 2 meters in upper river sections and up to 4 meters in lower river sections.

There are two primary models of the structure of natural aggregate deposits in the Carpathians:

- deposits with one type of mineral – mainly gravel,
- alluvial deposits with a layered structure with the upper layer being sand-gravel, and the bottom – gravel.

There are five subtypes within the first model:

- short-range deposits with small thickness, as well aspoor quality minerals of the mountain sections of rivers and streams flowing down a narrow, deep, indented valley, for example the Trzciana deposit on the Jasiołka River (Photo: 2) and the Drymak deposit.
- small-range deposits, gravel or gravel-sand sediments under considerable overburden of delluvia; they are of little significance as raw materials. They can be found at higher Pleistocene river terraces, quite high above the valley bottom;
- large-range deposits, of varying thickness, over burden of variable, usually small, thickness, and favorable overburden/deposit ratio. Characteristic of flood and meadow terraces of mountain sections of the Carpathian rivers. Examples of such deposits are: Krempachy and Trybsz;
- large-range deposits, very thick with large overburden, where sand-gravel aggregate is the mineral;
- large-range deposits comprising river bends, various degree of thickness, large overburden; typical of meandering rivers. Examples: Targowisko-Zakole deposit (Photo 3) and Damienice-Zakole Raby deposit.

Photo 1. Myscowa deposit on the Wisłoka River (by P. Kowalski)
Zdjęcie 1. Złóże Myscowa na rzece Wisłoka (P. Kowalski)

Photo 2. Mining of Trzciana II deposit (by A. Kowalska)
Zdjęcie 2. Wydobycie ze złóża Trzciana II (A. Kowalska)

Photo 3. Mining of natural aggregate deposit Targowisko-Zakole on the Raba River (by A. Kowalska)

Zdjęcie 3. Wydobywanie kruszywa naturalnego ze złóża Targowisko - Zakole na rzece Raba (A. Kowalska)

In terms of their petrography, the Carpathian gravel sediments are sandstone gravels. An exception is gravels in streams and rivers flowing from the Tatra Mountains – they are classified as sandstone-granite-quartzite gravels – and deposits of sandstone gravel with menilite cherts, occurring in the river valleys of Biała, Wisłok, Wisłoka and San.

The deposits located in the Carpathianshave resources below 1 million tonnes. Two deposits – Czarny Dunajec and Czarny Dunajec-Zbiornik – are an exception.

Mining Of Sand And Gravel Vs. The Natural Environment

Natural aggregate extraction interferes with the natural environment, deforming all environmental components within the mining site and its surroundings (Kowalska 2010). Impact exerted by open-pit extraction may be periodic, long-term or irreversible (Table 2).

Noise ispresentat the preparatory stage, as well as in the course of mining and reclamation. It is caused by the operation of extracting machines, processing equipment and by the transport of raw material sandwaste. Also gases and dust are emitted at each stage. The source of fugitive gas emissionsis the fuelin the engines of motor vehicles and mining machines, while the source of dust emissions is the removal andstoring of overburden, transport by trucks and mining ofraw materials.

Long-term changes do not end when management of a deposit comes to an end, but they may be reversible. Geochemical changes in water and soil may occur as a result of dust and oil/fuel leaks from motor vehicles or machinery. The water used in the treatment process works in a closed system. It is usually transported to the excavation voids in the form of turbidsuspension, which rapidly turns into a sediment. There is often a depression cone as a result of aggregates mining, and hence the level of water in wells decreases. Soils dry up. Aggregate deposits are typically found in agricultural landsorin forests, which are excluded from their original function. Large water-filled excavation voids cause changes in the local climate.

In the course of extraction, a number of irreversible changes take place. All mineral deposits are precious environmental elements and are under protection, as required by the sustainable development principle (Nieć, 2008; Sobczyk andKowalska, 2013). Excavation voids have a permanent impact on the area morphology and they change the landscape irreversibly. Ecosystems undergo degradation – mainly due to removal of the soil layer where animals and plants live. A destroyed ecosystem will never be restored to the original condition. There is a chance, however, that after reclamation or due to secondary succession, new ecosystems will be created, perhaps even more valuable (Frankiewicz and Glapa, 2007).

Once extraction is over, post-mining sites undergo reclamation with respect to biological diversity. If the mining takes place in an impoverished natural environment, post-industrial areas may become a habitat for wild avifauna, thus contributing to maintaining biodiversity. The following species may build their neststhere: swallows, falcons, pheasants, wagtails, linnets, and night herons. Furthermore, reclaimed areas form ecological corridors between priority protected areas. This improves the cohesion of Natura 2000 areas. Open-pit mines offer favorable conditions for the habitats of roe deer, deer, foxes, hares, and ermines. Post-extraction sites are quickly inhabited by lizards, mountain toads, snakes, grass snakes, and slowworms.

Sometimes reclamationis the beginning of a new, more attractive land use. If reclamation is abandoned, often favorable conditions develop for the settlement of new species of plants and animals. However, more often than not, the lack of reclamation contributes to erosion,surface mass movements, changesin the ecosystem, eutrophication of water bodies and formation of landfills. With environmental restrictions imposed on mining activityin Natura2000 areas and other

Tab. 2 Changes in the environment caused by open-pit mining (Kowalska, 2013)

Tab. 2 Zmiany w środowisku spowodowane przez górnictwo odkrywkowe (Kowalska , 2013)

Periodic changes	Long –term changes	Irreversible changes
noise	geochemical changes in water and soil	depletion of minerals
air dusting	changes in water circulation	changes in area morphology
air pollution with exhaust fumes	change in land use	landscapetransformation
	localclimate	degradation of ecosystems

forms of nature and landscape conservation, mining may become difficult to perform there. Almost half of documented reserves of natural aggregates in Małopolska can be found in Natura 2000 areas (Czaja and Kozioł, 2010).

If the basic building material (i.e. natural aggregates) is to remain abundant in Poland in the near future, the real environmental impact of mining industry should be assessed on the basis of active gravel pits. Then an optimum solution should be found for the two parties involved, taking into account the expectations of the mining industry and the need to protect habitats and species in danger of extinction in the EU.

Summary

It is a common belief that open-pit extraction of natural aggregates has a highly adverse impact on the environment, including landscape. As a result of sand and gravel extraction habitats may be transformed, decreased in size, fragmented or destroyed. The degree of their degradation depends on the location and size of the mining plant and of related infrastructure, on the methods of deposits mining, and on environmental factors and ecosystem resistibility.

The Natura 2000 network is in conflict with the mining industry due to the nature of mineral deposits. Many protected areas have been established within managed and unmanaged deposits of sand and gravel, which poses a potential threat that extraction will be abandoned.

In order for the mining industry not to be perceived as a negative factor, but rather as an activity which brings new quality, proper reclamation of post-mining sites should be introduced. With consultations with local communities and targeted activities, the degraded area may become an attractive habitat for many species of animals, plants and mushrooms. Moreover, it must be remembered that in many excavation pits, especially following illegal extraction, the process of secondary succession has been observed. Unreclaimed excavation pits are inhabited by new species of animals and plants.

If we decide to follow the principle of sustainable development, we should use the environment in a way that will keep it in the best possible condition for future generations. One should bear in mind that the adverse consequences of the current activity will become a burden for our descendants. Because of that, all of us are obliged to utilize deposits rationally.

Development of mining of natural aggregates is a chance for Poland’s economic growth. It must, however, remain in harmony with the natural environment.

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Streszczenie

W artykule scharakteryzowano dynamikę wydobycia piasków i żwirów na terenie polskich Karpat. Ograniczenia ekologiczne eksploatacji piasków i żwirów w obszarach Natura 2000 i w innych formach ochrony przyrody i krajobrazu powodują, że będzie to skutkować trudnościami w działalności górniczej na tych terenach. Sieć Natura 2000 znajduje się w konflikcie z przemysłem, zwłaszcza z górnictwem odkrywkowym. W obrębie zagospodarowanych i niezagospodarowanych złóż piasków i żwirów wyznaczono wiele obszarów chronionych. Stwarza to potencjalne zagrożenie zaniechania eksploatacji.

Aby górnictwo nie było postrzegane jako czynnik o negatywnym oddziaływaniu, ale jako działalność wnosząca nową jakość, należy prowadzić odpowiednią rekultywację terenów poeksploatacyjnych. Wiele kopalń odkrywkowych po zakończonej eksploatacji jest poddanych rekultywacji pod kątem różnorodności biologicznej. Jeżeli wydobycie jest prowadzone w już zubożonym środowisku naturalnym, to powstałe obszary mogą stać się siedliskiem dla dziko żyjących gatunków, a nawet tworzyć korytarze ekologiczne między priorytetowymi obszarami chronionymi. Wpływa to na zwiększenie spójności sieci obszarów Natura 2000. Miejsca po eksploatacji kopalin stwarzają dogodne warunki siedliskowe dlasaren, jeleni, lisów, zajęcy, gronostajów, jaszczurek, kumaków, zaskrońców. Gniazdują tu sokoły, bażanty, makolągwy, ślepowrony.Oddziaływanie górnictwa odkrywkowego na krajobraz nie jest jednoznaczne, gdyż walory wizualne danego terenu mają charakter subiektywny.

Dzięki konsultacjom społecznym i ukierunkowanym działaniom zdegradowany teren może stać się atrakcyjny pod względem możliwości zasiedlania przez wiele gatunków zwierząt, roślin i grzybów. W przypadku zaniechania rekultywacji mogą zajść negatywne zmiany: erozja, powierzchniowe ruchy masowe, zmiany w ekosystemie, eutrofizacja zbiorników wodnych.

Rozwój górnictwa kruszyw naturalnych jest szansą na rozwój gospodarczy Polski. Musi jednak pozostać w zgodzie ze środowiskiem naturalnym.

Słowa kluczowe: górnictwo, złoża piasków i żwirów (kruszywa naturalne), ochrona środowiska, ochrona przyrody, Natura 2000