Raw Materials from anthropogenic fields

Urząd Marszałkowski, Wrocław, 12.12.2017

Mining waste

Wiktor Kowalczyk

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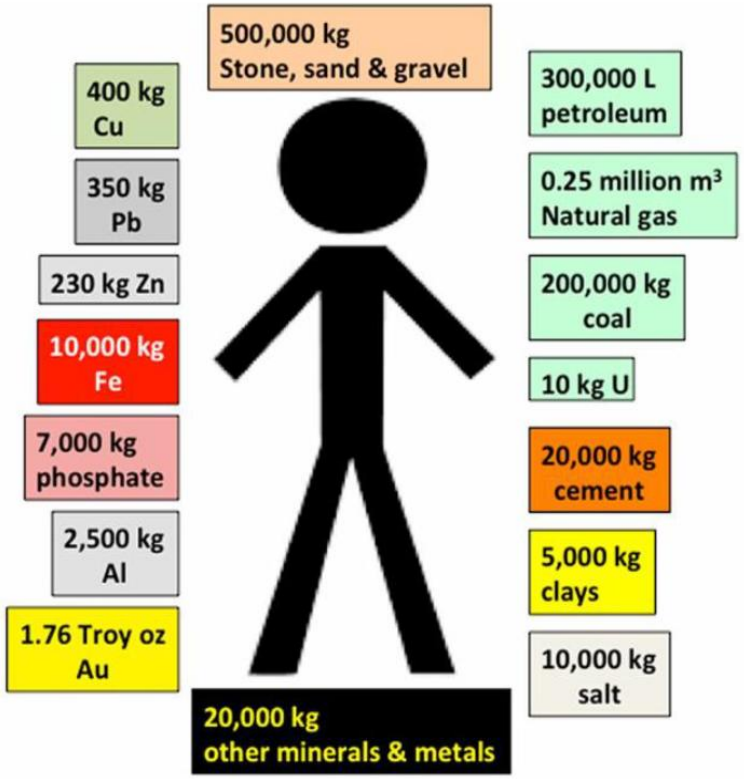
Raw Materials

The global groth of raw materials demand, the sustainable supply of minerals and metals is of general concern

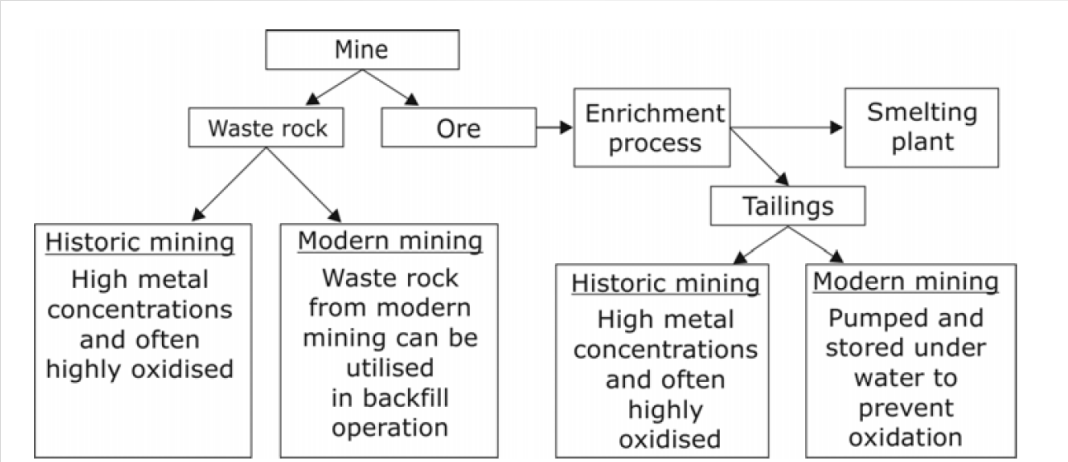


1.4 million kg of metals, minerals and fuels in a single lifetime

Average lifetime consumption of resources for individuals (from Kyser *et al.*, 2015)

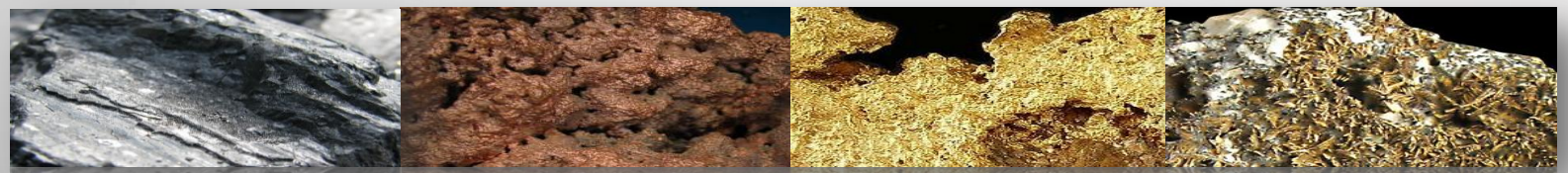
Mining waste

Due to geological variety and the continuous nature of minerals' processing plants, tailings dams normally contain large quantities of metals and other valuable elements that could have been recovered. Waste products of mining, enrichment of minerals and industrial rocks very often can be used as a second hand by-products



Principal mining schedule. Mainly two waste products are generated from mining activities: waste rock and tailings

Source: Sartz 2010



Mining waste in Poland

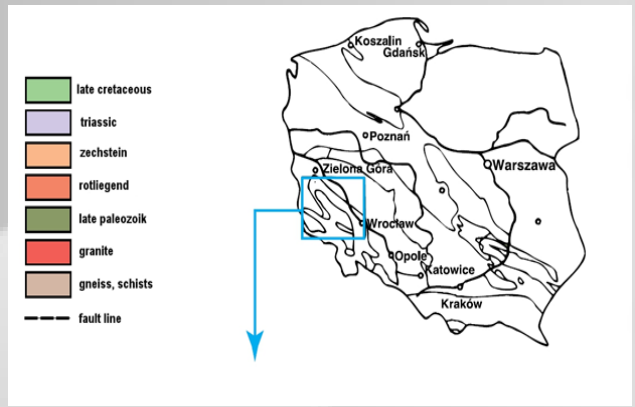
- The majority of mining wastes in Poland are generated in the three southern voivodeships: Śląskie (28%), Dolnośląskie(28%) and Małopolskie (5%)
- According to official data of the Polish Central Statistical Office, wastes from mining and processing (waste code 01) are the largest group of wastes generated and deposited in Poland
- The three main types of such wastes in Poland are (Environment 2012, Galos et al. 2009):

  1) wastes from mining and processing of hard coal,

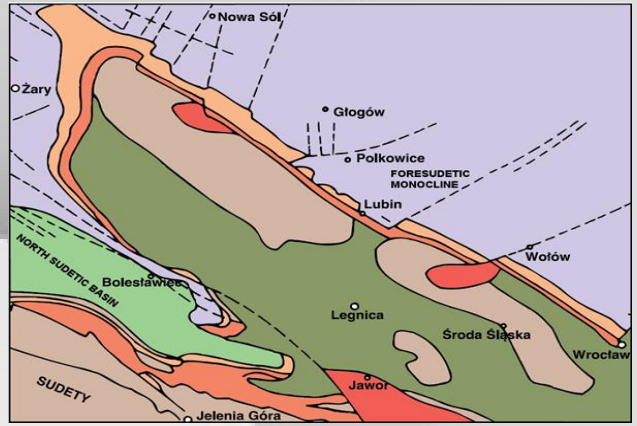
  2) wastes from mining and processing of non-ferrous metals ores,

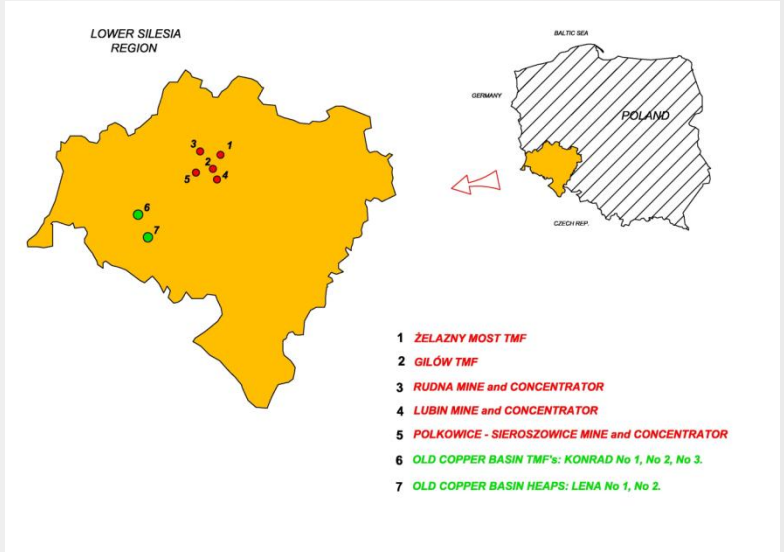
  3) wastes from rock minerals extraction

Copper ore basins in Lower Silesia



- The location of cooper ore basin in Lower Silesia Region is presented on the pictures
- The Licence for exploitation of copper ore beds in LGOM belongs to KGHM POLSKA MIEDŹ S.A.
- Currently the copper ore is extracted by three mines: Lubin, Rudna and Polkowice-Sieroszowice; the ore is enriched in three concentrators, which prepare concentrate for smelters
- Location of these objects is presented below. The object of not operating „old copper basin" is market as well





Mining waste

The mining waste, which is generated in copper basin region is waste rock. The waste rock, produced by developing the deposit and mined together with copper ore, is used as it comes in the mine - for filling the cavities, as a subcrust under supporting cribs or for hardening the mine headings

The only mining waste extracted at present onto the surface is waste rock produced during shaft drilling

Waste rock deposition places (heaps)

Name and location of the object	Owner	Surface [ha]	Amount of deposited material [Mg]	Status
PW Polkowice	Polkowice – Sieroszowice Mine	5, 34 ha	767 036 Mg	Closed, partially reclaimed
PZ Szklary Górne	National Forests	5,9 ha,	847 474 Mg	Closed, reclaimed
P VII Jędrzychów	National Forests	5,89 ha	846 800 Mg	Closed, reclaimed
PG Polkowice	Polkowice town	8,0 ha	950 000 Mg	Closed, reclaimed
PW Polkowice Dolne	Polkowice – Sieroszowice Mine	5, 34 ha	767 036 Mg	Closed, reclaimed
Hałda SW-3 Sieroszowice	Radwanice district	2,4 ha	75 000 Mg	Closed, reclaimed
Hałda SW - 1 Bądzów	Polkowice - Sieroszowice Mine	6,96 ha	626 148 M	Closed, reclaimed
Hałda SG Jakubów	Polkowice- Sieroszowice Mine	7,34 ha	474 000 Mg	Closed, partially reclaimed
SG-new	Polkowice-Sieroszowice Mine	1,86	Ultimately 150 000 Mg	Running
RG Trzebcz	National Forests	5,11 ha	1 010 640 Mg	Closed, reclaimed
RZ Polkowice	Land Estate Agency of State Treasury	5,0 ha	826 764 Mg	Closed, reclaimed
R VII Tarnówek	Land Estate Agency of State Treasury	2,20 ha	242 394 Mg	Closed, reclaimed
R VIII Pieszkowice	National Forests	7,68 ha	170 483 Mg	Closed, reclaimed
R IX Komorniki	National Forests	4,10	245 019 Mg	Closed, reclaimed
LW	National Forests	3,38	847 000	Closed, reclaimed
LVI	National Forests	3,0		
LG	National Forests	11,9		
LZ	National Forests	4,5		

Because of kind of developed deposit, in the Polska Miedź SA mines the sandstone and dolomite waste rock is produced.

Dolomites are hard and compact rocks. It is built by calcite and dolomite in the form of fine crystals. Dolomites and limestones displays compressive strength over 40 MN/m2, often 100 and more MN/m2.

Sandstones are quartz sandstones, mainly fine grained, of red-brown colour and psammite structure. Binding material of sandstones is clayish or clayish - carbonate. Some parts of material contains significant amounts of salt.

Mineral processing waste

The ore extracted from the mines in the form of rock chunks contains around 2% of copper. It is processed into concentrate in 3 Ore Enrichment Plants (concentrators):

ZWR Lubin,

ZWR Rudna,

ZWR Polkowice

The plants annually produce over 2 million of concentrate containing up to 30 % of copper and the main waste : flotation tailings

Flotation tailings in KGHM Polska Miedź SA represent around 94% of extracted ore and amount to around 29 mln tones annually. They leave the concentrators in a form of water suspension and in this form are delivered to the ŻELAZNY MOST

Average mineral composition of flotation tailings

Mineral	Concentrator / Content [%]	
	Lubin, Rudna	Polkowice
Dolomite	29,95	58,3
Quartz	44,46	6,85
Calcite	7,70	7,82
Kaolinite	4,76	3,29
Gypsum	1,65	4,70
Biotite	3,30	1,12
Feldspar	1,35	0,82
Claylike-carbonate substances	8,35	4,78
Ore materials	1,10	1,32

Calcium and magnesium in flotation tailings are present as carbonates, heavy metals as sulphides : Cu as chalcocite (CuS), bornite (Cu5FeS4), chalcopyrite (CuFeS2), covellite (CuS); Pb mainly as galena (PbS), zinc and nickel in a form od sulphides as well and often as silicates. Alcaline character of waste minerals (pH of water extract = 7,5 – 8,5) in practice prevents the sulphides oxidation reaction to dissolved forms

Mineral processing waste in Rudna mine

- Subjected tailings are generated during copper ore enrichment process (flotation) in Rudna Ore Enrichment Division. The concentrator in Rudna uses a conventional flotation process to produce 25–26 % copper concentrates for the smelters. During the process copper minerals are separated from worthless material by inducing them to gather in and on the surface of a froth layer. The process entails crushing and grinding the ore to a fine size, subjected to flotation with addition of flotation agents in flotation cells, after which the concentrate is thickened, filtrated a dried and tailings, in a form of slurry is directed to the deposition place

Average mineral and chemical composition of flotation tailings from OED Rudna,

Component	Content	Component	Content
SiO_2	53.3 %	F	420.0 g/Mg
MgO	4.73 %	Mo	17.0 g/Mg
CaO	16.66 %	Hg	17.0 g/Mg
Al_2O_3	4.20 %	V	81.0 g/Mg
Cu	0.24 %	Pb	0.05 %
Zn	0.01 %	Fe	0.38 %
S	1.02 %	Cl	3.01 %
C	3.22 %	Na	1.91 %
Ag	7.40 %	K	1.18 %
As	20.0 g/Mg	Ni	14.0 g/Mg
Cd	2.6 g/Mg	Mn	13.0 g/Mg
Co	13.0 g/Mg	Au	8.0 mg/Mg

- Flotation tailings are ground waste rock of inert chemical character, which basic components are quartz and dolomite. In flotation tailings from OED Rudna sandstone is prevailing component

Flotation tailings management facility Żelazny Most

- Flotation tailings from current production are directed to Żelazny Most. The object is situated administratively in the Voivodeship of Lower Silesia, mainly in Rudna district

- The qualities of the flotation tailings deposited on Żelazny Most is given above.
  Basic parameters of that facility, which is the largest in Europe object of this type, are given below:

TMF total surface	- 1 394 ha,
surface of beaches	- 899 ha,
surface of the overtailings water	- 495 ha,
amount of deposited tailings	- 667,7 mln Mg,
volume of deposited tailings	- 486 mln m3,
volume of overtailings water	- 8,5 mln m3,
length of dams	- 13,4 km,
height of the dams	- 172,5 – 175 m over the see level

Flotation tailings from old Copper Basin

- During 1953– 1978 the copper ore was extracted in so called “Old Basin” of Copper. The area is located in south-west part of Poland, in Lowersilesian Province, between Bolesławiec and Złotoryja towns near the Warta Bolesławiecka and Iwiny villages. Copper ore was extracted by the mine KONRAD, then was enriched in concentrators, and the flotation tailings were deposited

- Flotation tailings from Old Copper Basin differ from these ones generated now. Tailings were generated by processing of shale - calcareous ore, in which prevailed margles and limestones and clay lime minerals of very fine granulation, mainly below 0,06 mm

Average composition and granulation of copper ore flotation tailings deposited on the objects of Old Copper Basin

Component [%]	LENA Mine	KONRAD Mine
CaO	27,06	23,68
MgO	3,54	4,42
SiO2	26,18	29,18
Cu	0,13	0,16
Pb	0,002	0,007
As	0,003	0,004
Al2O3	8,83	10,24
Co [g/Mg]	20	23

Flotation tailings from old Copper Basin

Not reclaimed flotation tailings management facility Konrad No 3 in Old Copper Basin in Iwiny village

Not reclaimed flotation tailings management facility Konrad No 1 in Old Copper Basin, near Iwiny village.
The natural succession on the objects is very slow and rather poor

Waste rock heaps

The closed by the end of last century waste rock deposition places are in different stage of reclamation. On several (like for example waste rock heaps of Rudna and Lubin Mine), the biological reclamation is full, the surface is covered by forest and other plants, they are the part of surrounding green areas and became animals sanctuary. All of Copper Basin waste rock heaps are reclaimed into forest direction

Completely reclaimed R-VII heap of waste rock - the surface covered by dense, healthy, about 25 years tree stand

Closed, but not reclaimed waste rock heap SG

The only one currently operated, new waste rock deposition place in Jakubów

Copper industry wastes

From above comes, that from the copper industry in Lower Silesia there are following materials, which can be the subject of interest:

- up to 30 mln Mg/year of flotation tailings generated currently by concentrators of KGHM;
- 810 mln Mg of flotation tailings deposited in ŻELAZNY MOST TMF (Tailing Management Facility)
- 68 mln Mg of flotation tailings deposited in closed GILÓW TMF
- 37 mln Mg of flotation tailings deposited in closed flotation tailings facilities in so called “Old Copper Basin”
- up to 50 000 Mg of waste rock deposited in not reclaimed heap.
- up to 200 000 Mg of waste rock, which will be generated in nearest future
- up to 3000 Mg/year of wooden pulp from concentrators

Management of flotation tailings

The most rational and environmentally friendly solution is to dispose them underground where the ore was previously extracted from. The flotation tailings, dewatered to a paste form and containing certain amount of binding agents, can be used as hardened backfilling material for structural support in underground mines.

Other feasible directions of utilization of the copper ore flotation tailing are applications of the tailings as secondary raw material. It can be used as a filler for bituminous pavement and also as a source of rare accessory minerals dispersed in the original ore and residual principal metals remaining in tailing.

Copper flotation waste from KGHM can be potentially used as sorbent in heavy metals removal from aqueous solutions.

Areas of concern

- The mining industry has begun to incorporate the concepts of sustainable development and sustainable mining practice across the life cycle of mineral operations
- Complete characterization of all materials to identify the presence of specialty metals (eg rhenium in copper ore bodies), combined with a value-based conception of waste that estimates the resource value of the materials. This should be supplemented with a rethinking of the waste hierarchy in the context of mining and mineral processing so that there is not an automatic presumption of disposal
- The EU is working to devise a new mineral policy, the goal of which will be to incorporate both primary and secondary minerals in mineral supply/production policy. If mine waste and tailings are to be redefined as sources of secondary materials, there will need to be coordination across government agencies to ensure that the rules within one domain do not conflict with rules in another
- Careful record keeping of material movement to waste rock and tailings facilities is essential to allow future identification of material locations. Without having good records of material locations, selective re-mining may not be possible

Wiktor Kowalczyk

Thank you for Your attention

Wrocław, 12.12.2017