FIRES IN MINE WASTE DUMPS
AND CONNECTED HAZARD FOR ENVIRONMENT,
POLISH EXPERIENCES

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1. Waste material from coal mines in Poland
2. Fire hazard on coal waste dump
3. Gases emission to the atmosphere
4. Prevention and extinguishing
1. Waste material from coal mines in Poland
Production of coal waste in Poland (GUS)

1 tone of coal → around 0.4 tone of waste material
Coal waste utilization in Poland (GUS)
Until recently there were 136 coal waste dumps inside The Upper Silesia Region and approx. 750mln Mg of waste material were being located there. Total area was approx. 3500ha.

Coal waste dumps are located mainly in central part of The Upper Silesian Coal Basin, near the cities: Ruda Śląska, Zabrze, Bytom, Katowice and inside Rybnik Coal Region.
The coal waste dump “Skalny” of Bolesław Smiałý Coal Mine in Laziska Gorne

The coal waste dump „Szarlota” of Rydułtowy-Anna Coal Mine – the largest conic dumps in Poland
Mineral composition of mine wastes in Poland, % (Skarżyńska 1997)

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Content, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illite</td>
<td>28 - 82</td>
</tr>
<tr>
<td>Kaolinite</td>
<td>9 - 65</td>
</tr>
<tr>
<td>Mixture of layers: sility-montmorillinite</td>
<td>0 - 5</td>
</tr>
<tr>
<td>Chlorite</td>
<td>0 - 10</td>
</tr>
<tr>
<td>Quartz</td>
<td>3 - 37</td>
</tr>
<tr>
<td>Pyrite</td>
<td>0 - 8</td>
</tr>
<tr>
<td><strong>Coal substance</strong></td>
<td><strong>15 - 30</strong></td>
</tr>
</tbody>
</table>
Petrography composition of coal wastes in The Upper Silesia (Skarżyńska 1988)

<table>
<thead>
<tr>
<th>Kind of rock</th>
<th>Content, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Claystones</td>
<td>40 – 98</td>
</tr>
<tr>
<td>Mudstones</td>
<td>2 – 40</td>
</tr>
<tr>
<td>Carbonaceous shales</td>
<td>2 – 25</td>
</tr>
<tr>
<td>Sandstones</td>
<td>0 – 33</td>
</tr>
<tr>
<td>Coal</td>
<td>3 – 10</td>
</tr>
</tbody>
</table>
2. Fire hazard on coal waste dump
Fires exogenous – external heat sources

Fires endogenous – oxidation of coal substance

There are three necessary conditions causing endogenous fire process:

• presence of sufficient quantity of a flammable material,

• easy air flow to the inside of a dump,

• possibility of heat accumulation in a dump.
In the presence of air and moisture, the reactions with significant heat output proceed on the surface of coal grains included in wastes:

\[
\begin{align*}
C + O_2 & \rightarrow CO_2 + Q \\
2C + O_2 & \rightarrow 2CO + Q \\
C + 2H_2O & \rightarrow CO_2 + 2H_2 + Q
\end{align*}
\]

In addition, the other reactions occur:

\[
\begin{align*}
C + CO_2 & \rightarrow 2CO - Q \\
C + H_2O & \rightarrow CO + H_2 - Q \\
C + 2H_2 & \rightarrow CH_4 - Q
\end{align*}
\]

where: Q - heat
And next exothermic reactions:

\[
2\text{CO} + \text{O}_2 \rightarrow 2\text{CO}_2 + 570,2 \text{ kJ/mol}
\]

\[
2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O} + 231,5 \text{ kJ/mol}
\]

\[
\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O} + 890,9 \text{ kJ/mol}
\]

\[
\text{CO} + \text{H}_2\text{O} \rightarrow \text{CO}_2 + \text{H}_2 + 40,4 \text{ kJ/mol}
\]

Oxidation of pyrite, sulfur and hydrogen sulfide:

\[
2\text{FeS}_2 + 7\text{O}_2 + 2\text{H}_2\text{O} \rightarrow 2\text{FeSO}_4 + 2\text{H}_2\text{SO}_4 + Q
\]

\[
\text{S} + \text{O}_2 \rightarrow \text{SO}_2 + Q
\]

\[
2\text{H}_2\text{S} + 3\text{O}_2 \rightarrow 2\text{H}_2\text{O} + 2\text{SO}_2 + Q
\]
3. Gases emission to the atmosphere
Burning surface of coal waste dump – gases emission to the atmosphere
Measurements of gas velocity and of concentration of gases
Mean concentration $S_i$ and values of emission $E_i$ of the basic fire gases from unitary surface ($1m^2$) of thermally active dump

<table>
<thead>
<tr>
<th></th>
<th>CO₂</th>
<th>CO</th>
<th>H₂</th>
<th>CH₄</th>
<th>C₂H₆</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S_i$ % vol.</td>
<td>4,363</td>
<td>1,1765</td>
<td>0,3614</td>
<td>0,27</td>
<td>0,048</td>
</tr>
<tr>
<td>$S_i$ g/m³</td>
<td>85701,79</td>
<td>14706,25</td>
<td>322,6786</td>
<td>2169,643</td>
<td>642,8571</td>
</tr>
<tr>
<td>$E_i 10^{-3}$ m³/s</td>
<td>0,13521</td>
<td>0,03646</td>
<td>0,0112</td>
<td>0,00837</td>
<td>0,00149</td>
</tr>
<tr>
<td>$E_i$ kg/year</td>
<td>8375,64</td>
<td>1437,24</td>
<td>31,54</td>
<td>212,04</td>
<td>62,83</td>
</tr>
</tbody>
</table>

Considering an assumption that there is hypothetical small dump with area equals 10 ha and intensive fire is at 5 % of surface (0,5 ha) and intensity of the process is constant, therefore total gases stream could be $15,5 m^3/s = 5580 m^3/h$.

Emission of selected gases from would be:

- $E_{CO₂} = 41 878,2$ Mg/year;
- $E_{CH₄} = 1 060,2$ Mg/year;
- $E_{CO} = 7 186,2$ Mg/year;
- $E_{H₂} = 157,7$ Mg/year;
- $E_{C₂H₆} = 314,15$ Mg/year.

Considering potential emission of $CH₄$ (Global Warming Potential for $CH₄$ is 21 times higher than GWP for $CO₂$) – annual emission of gases influencing and increasing green house effect equals $60 000 MgCO₂_{eq}$. 
Waste material temperature in examined area

- **Surface**: 85°C
- **Depth 0.25 m**: 151°C, 65°C
- **Depth 1.0 m**: 242°C, 200°C, 93°C, 250°C, 460°C, 400°C, 130°C, 463°C, 492°C
High temperature and limited oxygen access

low temperature carbonization or even coking
during which coal is under thermal decomposition (pyrolisys)

Other gas products which may be emitted:

- sulfur dioxide $\text{SO}_2$
- nitrogen dioxide $\text{NO}_2$
- aliphatic and aromatic hydrocarbons
- hydrogen sulfide $\text{H}_2\text{S}$
- coal disulfide $\text{CS}_2$

Dark stains at the surface – it's the effect of coal pyrolisys and condensation of its products

Smell discomfort
Dusting during operating process of the dump
4. Prevention and extinguishing
Monitoring - quick detection of the dumps thermal activity

Methods of the thermal state estimation:

• Observation of external symptoms of self-heating process,

• Control of the interior atmosphere of the dump, mainly the tests of CO, CO$_2$ contents as well as oxygen concentration drop,

• Waste material temperature measurement on the dump surface or/and inside it.
External symptoms of self-heating process

Flames, steam and fume emission of the dump surface
External symptoms of self-heating process

Disappearing of snow cover during winter time
External symptoms of self-heating process

- Dark stains on the surface
- Sulphur efflorescence at the fume emission places
Control of the interior atmosphere of the dump - mainly the tests of CO, CO$_2$ and O$_2$ contents
Measurement of waste material temperature

**Infrared Pyrometer** – measurements of surface temperature

**IR mapping (Thermovision)** as a way to control thermal activity of a dump

Phot. www.testo.pl
Measurement of waste material temperature

Measurement inside the dump

Thermometers with special temperature sensors (thermocouples)
Extinguishing and prevention of spontaneous fires on coal waste dumps

Prevention consists in reducing one of three conditions necessary to endogenous fire process. In practice it’s realized by:

- reduction of flammable components in waste material,
- cut off or limitation of oxygen access,
- limitation of heat accumulation possibility.

There are many methods used on Polish coal waste dumps with better or worse effects. It is a result of many years of experiences of research institutes, coal mines and companies dealing with land reclamation (Central Mining Institute, Institute of Mining SUT, Barosz-Gwimet and others).
High pressure injection of water-ash mixtures into a dump
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Building of absorptive trenches and filling them up with ash-water suspension
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Forming of thickened reclamation embankment around the dump and filling the area between the dump and embankment with ash-water suspension.
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Enclosure of a dump with compacted waste material and with special chimneys left - (chimney should be made from coarse-grained material)
Exploitation of burning material and its simultaneous cooling out
Extinguishing and cooling down the dump with inert gas (carbon dioxide)
Cooling and heat recovery from the thermal active coal waste dumps by vertical concentric heat exchangers
Reclamation of coal waste dumps

Reclamation of areas devastated by the industry (including coal waste dumps) is divided into four stages:

- preparation (documentation),
- basic (technical),
- detailed (biological),
- land development.

Coal waste dump of Rydultowy-Anna Coal Mine –
one of several reclaimed objects - recreational direction with sport objects
Conclusions

Two major directions:

- Basing on foreign experiences – necessity of reclamation and waste dumps management - significant outlay is required.

- Taking advantages from nowadays road engineering works – profits for Coal Companies and land recovery.

Alpine Center on coal waste dump in Bottrop
(phot. MGG)

Construction of A1 highway near Gliwice
(phot. A. Grygiel)
Thank you for your attention
References


