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# THE SUBSIDENCE CAUSED BY THE WASTE-COAL SELF-IGNITION PROCESS IN THE ANINA TOWN (ROMANIA). PRELIMINARY STUDY

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**Abstract**

Uncontrolled subterranean coal fires, mainly developed through the process of self-ignition, represent a challenging hazard of local dimension, but with global-scale distribution. One important effect of this spontaneous ignition process is the surface subsidence. Porosity and particle size fraction of the coal particles in the deposit, water and oxygen play the main role. Anina sterile heaps present a non-typical situation of waste-coal self-ignition. The fine coal is found in the sterile heaps distributed all over the actual urban area, being covered by human activities and residential buildings, so that, the human risk is present in several forms.

**Keywords:** *coal self-ignition, sterile-heaps, subsidence risk, Anina*

**Rezumat**

*Subsidența cauzată de autoaprinderea haldelor de steril din orașul Anina (România). Studiu preliminar.* Arderea subterană necontrolată a cărbunilor, de multe ori rezultat al procesului de autoaprindere, reprezintă un fenomen de risc de dimensiuni locale, dar cu distribuție la scară globală. Un efect important al acestui tip de arderi este subsidenta terenului. Porozitatea şi dimensiunea particulelor de cărbune din depozit, apa şi oxigenul joacă rolul principal. Haldele de steril din Anina prezintă o situație atipică de autoaprindere a cărbunelui mărunt înglobat în structura lor. Cărbunele mărunt apare în haldele distribuite pe toată suprafața urbană actuală, acoperite fiind de activitățile umane şi clădiri, astfel încât riscul uman înbracă mai multe forme de manifestare.

**Cuvinte-cheie:** *autoaprinderea cărbunilor, halde de steril, risc de subsidență, Anina.*

## INTRODUCTION

All over the world, spontaneous combustion represents a major risk during coal mining, but also after the resources exploitation, in the management of coal waste heaps. Problems with large-scale coal fires have been reported in China, USA, India, Indonesia and South Africa (Wessling et al., 2008).

The subsidence, as the effect of the coal mining activities, is a *geological risk* that might appear slowly with insignificant effects at the beginning and serious damage in the end. Unlike earthquakes and volcanism, this category of geological risk, when it occurs, affects a small number of people. If the phenomenon has negative impacts, for example on some important transport infrastructure, the number of those affected increases (by blocking an industrial or commercial stream etc.) (Fig. 1).

Subsidence as the effect of the mining activities is generally defined as the lateral or vertical slowly "sinking" of the earth, as the consequence of the present or past mine excavations which appear as underground cavities. There are also some other potential causes – physical, chemical, hydraulical – that may induce subsidence processes and new cause-effect geo-system dynamics. Our present case study refers to such a non-typical situation: the waste-coal self-ignition.

*Self-ignition* is caused by the exothermic reaction between coal and oxygen and the related release of thermal energy; if oxygen is sufficiently supplied, but the energy is not removed, the reaction becomes self accelerating until combustion occurs (Wessling et al., 2008).

**Site conditions. Human interference and implications.**

In the case of Anina town, the anthropic activity has changed the natural landscape (special the land forms and the natural vegetation) as a result of not only early underground mining, but also of the storage of excavation waste on vast lands and in many sites, all over the present urban area. Most of these heaps are hardly visible now because they are covered by big industrial platforms, buildings and natural vegetation (Fig. 2).

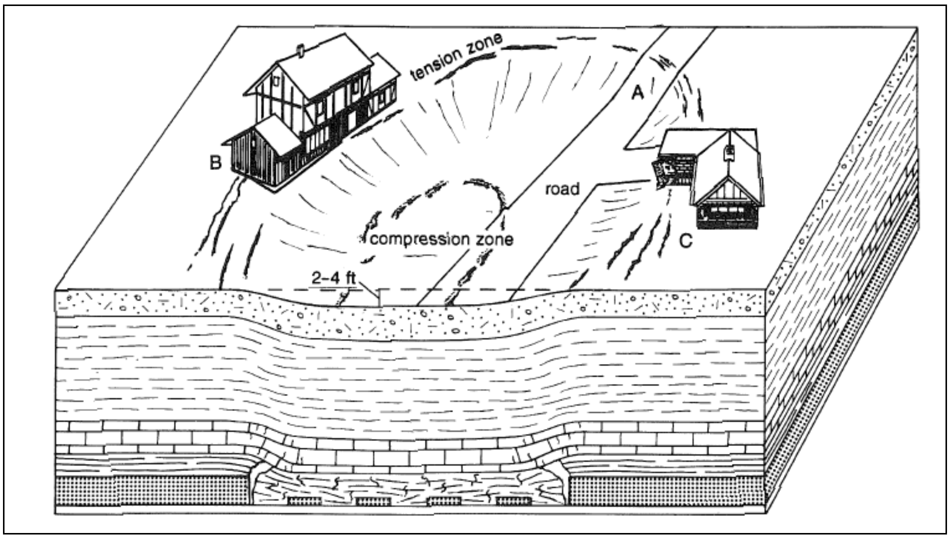


**Fig. 1 The surface affected by the subsidence trough (according to Bauer et al., 1993)**

Thus, the forms, the methods of manifestation and the impact on the geo-system are multiple, the direct ones – like temporary or permanent occupation of land surfaces, and the indirect ones – like the degradation of the relief forms and the landscapes, the air pollution, the degradation of groundwater and surface water; most of them are long term effects.

The entire city centre is built on some sterile-coal heaps dating from the first half of the 19th century, when the mining operation of Breuner pit started and when the whole economic activity made great strides (Fig.3).

In those days, the small parts of the coal mass were not used, so it had no economic value and it was thrown in the waste dump together with the sterile. Only later, starting with 1921 this was used to manufacture the metallurgical coke. The presence of such *lenses* of coal in the dump mass, together with a critical drainage led to the water penetration into the depth and, by oxygenation, brought to a phenomenon known as *self-ignition*. The small coal, in the presence of oxygen from water, kindles and starts smouldering. The phenomenon may last for days, weeks or even months, and it is distinguishable at the surface by thermal changes (such as the heat propagated in the sterile makes the ground to become warmer in some parts and releases heat in the atmosphere), by chemical changes (such as the elimination of a large quantity of carbon monoxide in the air that may be olfactory perceptible) or by mechanical changes (such as the structure and volume change of the dump leads to subsidence) (Fig.4).

Gas products from coal combustion have five different forms (Deng, 2010): between temperatures of 30~100°C, $H_2O$ and $CO_2$ are formed; when the temperature ranges from 105 to150 °C, CO is formed, and when temperature exceeds 170°C, $CH_4$ and $C_2H_4$ are produced. At Anina, the carbon monoxide seems to be the most dangerous, easily detectable by human smell; the gas rests near the surface and causes unfavourable air mass movements. (Fig. 5).

Due to the fact that the heat generation is a result of carbon oxidation reaction, the key parameters which influence the self-ignition can fall into three groups (Lohrer et al., 2005):

a. *material properties*: porosity, particle size fraction (tab.1-2), water content, heat inductivity, bulk density, specific heat capacity and diffusion coefficient of the material;
b. *surrounding deposit characteristics*: oxygen volume fraction, convection of air, relative humidity;
c. *the volume to surface ratio (V/A)* of the incandescent deposit area (Fig. 6).

After Chong (cited by Lohrer, 2005), the self-ignition is also affected by the penetration of water (if as liquid or vapour) into the void volumes. The process called by Lohrer *the heat of wetting*, the condensation phase of this water, represents an additional heat transfer, and consequently, the temperature inside the deposit increase much faster compare to the dry surrounding. One of the essential parameters that are disregarded in the management of the sterile heaps in Anina was/is *the drainage*.

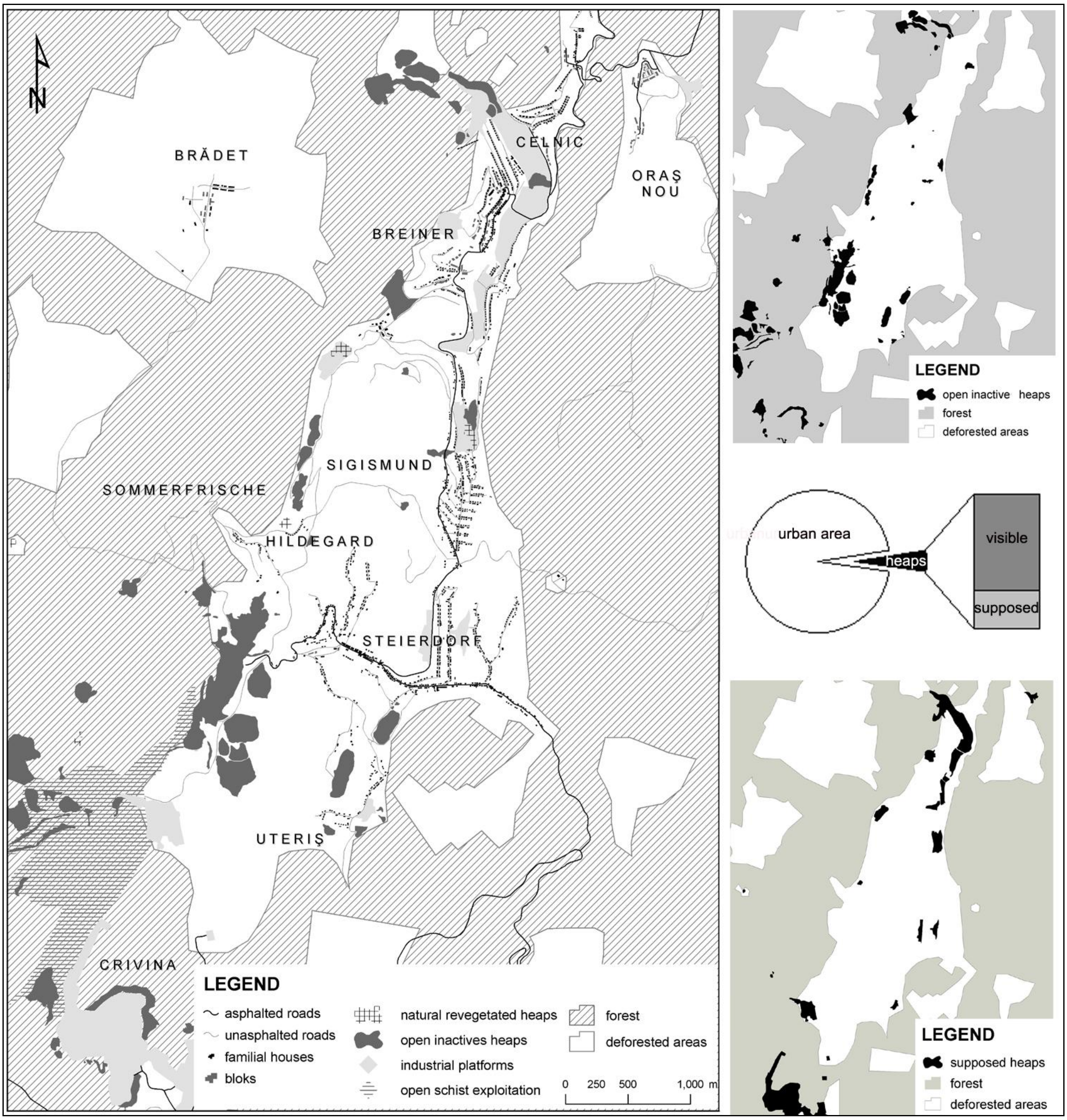


**Fig. 2 Spatial disposition of visible and supposed coal-heaps in the Anina urban area (Satmari, 2010)**

**Table 1**
**Particle size distribution of two fractions of coal in %***(according to Lohrer, 2005, modified)*

| Particle fraction (µm) | Fraction A (%) | Fraction B (%) |
|---|---|---|
| <20 | 25.3 | - |
| 20-40 | 20.7 | - |
| 40-63 | 18 | - |
| 63-125 | 20 | - |
| 125-200 | 11 | 9.8 |
| 200-315 | 5 | 4.3 |
| 315-500 | - | 2.4 |
| 500-1000 | - | 10.1 |
| 1000-2000 | - | 60 |

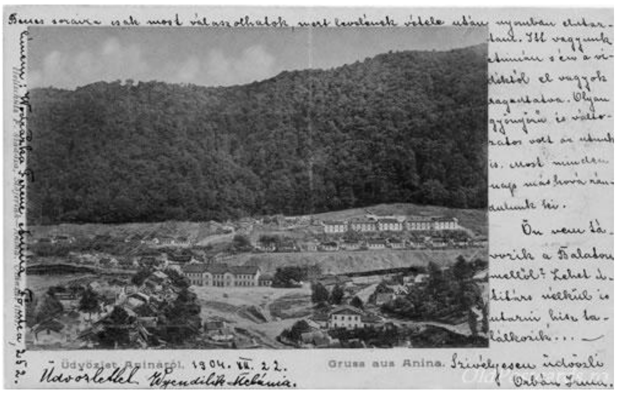

**Fig. 3 Anina at the year 1904, a town built over a heaps-land. (www.oldpostcards.ro)**

**Table 2**
**Self-ignition temperatures (SIT) experiments for coal**

| Volume (mL) | Fraction A | Fraction B | obs. |
|---|---|---|---|
| 31 | 138 | 140 | The biggest |
| 100 | **124** | **129** | deviation |
| 400 | 113 | 112 | Equal SIT |
| 800 | 110 | 110 | |

*(according to Lohrer, 2005, modified)*

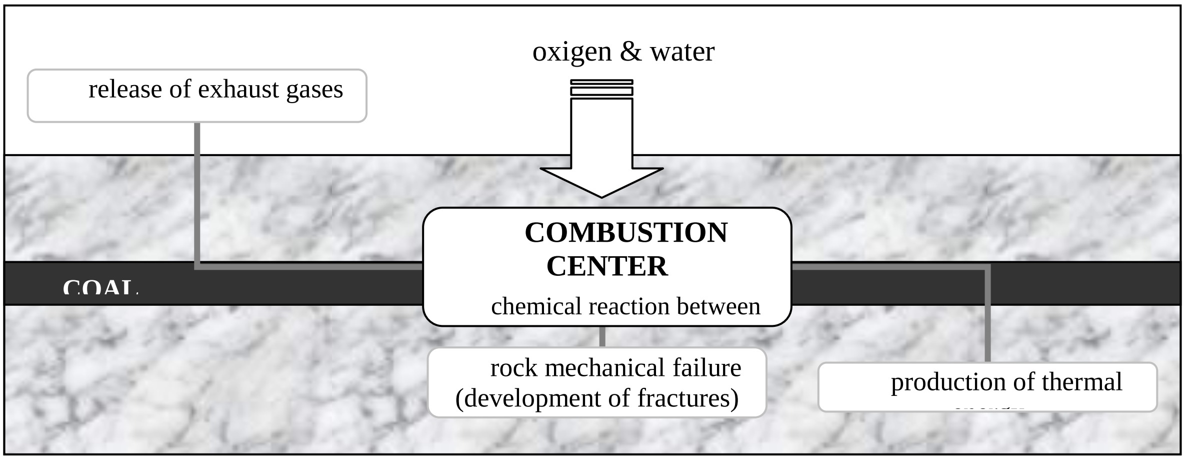


**Fig. 4 Coal self-ignition in heaps deposits scheme (according to Wessling, 2008, modified)**

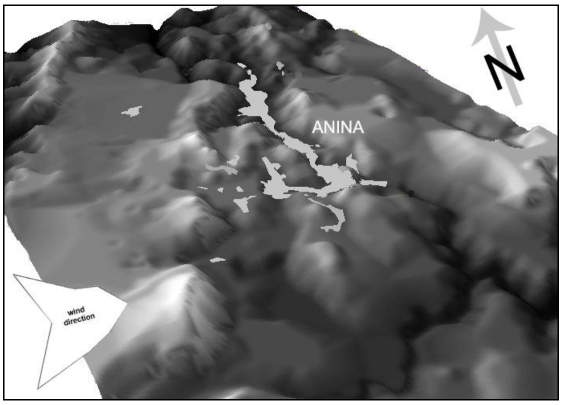


**Fig. 5 The local geomorphology and the wind frequency do not help CO ignition product to disperse. (Satmari, 2010)**

A special case refers the dump fire in the central park of the town. The dump was made between 1851 and 1900 from the operating sterile of Thinfeld I pit; the sterile contained sandstones, stone, schist, shale and coal dust. This dump occupies a total area of about 14 sqkm, and its thickness is about 14 m. The discharge of hot ash at the base (bottom) of the dump was the cause of the fire in the winter of 1986-1987 that lasted more than 20 years, until 2002. Among the damages, it is worth mentioning: the subside and settlement of the heating station, the first railway line and the out- of-use wagon scales, the park of the town became uneven and the vegetation was destroyed, the road to Steierdorf became uneven, the apartments on the ground floor of Block G and the shops on the ground floor of Block E were invaded by smoke and vaporous (other related possible risk is the carbon dioxide accumulation near the soil surface).

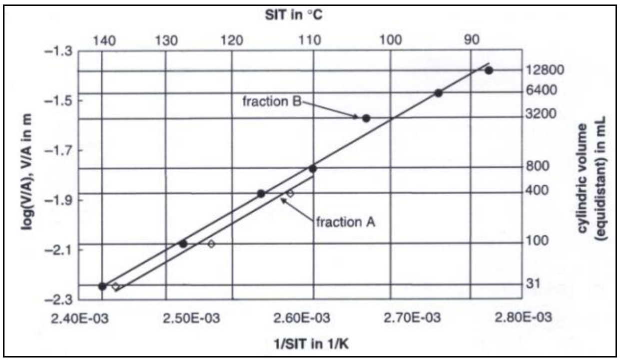


**Fig. 6 The local geomorphology and the wind frequency do not help CO ignition product to disperse. (Satmari, 2010)**

At present the fire is less intense, but it still burns, because the recent dynamic of its effects are visible at the surface by the land subsidence of the small buildings located on the dump (Fig.7). The part of the road that crosses the centre of the town has been raised several times in order to be used.

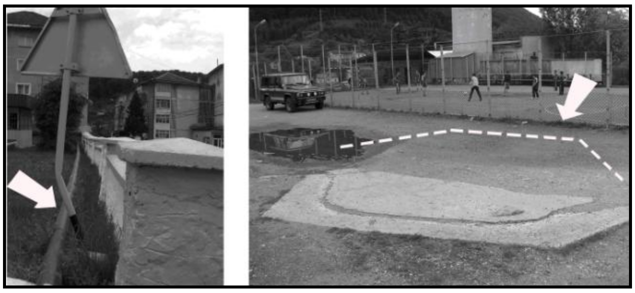

**Fig. 7 Subsidence consequences in the central park of Anina (Satmari, 2007)**

A study made by an international team of volunteers and coordinated by an NGO from Romania (Hobby Club Jules Verne Buziaş) specifies some data measurements taken in September 2002: at that time in Breiner centre, in the collective block-dwellings, the drinking water feed pipes had a temperature of 50-60°C and the ground continued to present some sinking tendencies and thus increasing the cracks in the walls nearby.

The main site conditions that caused the self-ignition and maintained the underground combustion were: the presence in the sterile mass of some small coal lenses with high humic acids content (this characteristic gives them a higher speed self-ignition), facilitating the oxygen absorption by the uncovered slopes of the dumps and the high degree of the settlement (this influences both the self-ignition and fire spread), the presence of heavy buildings such as the multi-story buildings and a heavy lorries road traffic.

## CONCLUSIONS

In Anina, the coal self-ignition risk area overlaps the area where the society has developed, being covered by human activities and residential buildings. This situation makes the risk of self-ignition more dangerous. Over the years, the subsidence affected small proportions of the ground surface, but in many local sites.

The presence of water (vapour, liquid, moisturised) and the possibility of heaps oxygenation are the uncontrollable starting factors of the spontaneous combustion of old coal exploitation heaps in Anina.

Due to the studies that were made, the phenomenon can be stopped by injection of a small-diameter drillings (a mixture of water, cement, ash and other aggregates) in the heaps-mass (Toth et al., 2010).

The properties of this mixture might play the greatest role in the success of the operation: the ability to flow (due to the liquid content and the sliding property of the ash particles), the type of aggregate (it directly affects the capacity of water discharge), the setting time, the hardness of the stiffened blending. But, because the cost of this “treatment” is too high, and the municipality doesn’t trust the phenomenon until the human risk appears, the uncontrolled self-ignition still occurs.

The human history shows us today that the progress has always its price, that wealth and poverty can succeed each other. In our opinion, the sustainable development and economy is the pair of antonymic situations which continues to define the $21^{st}$ century.

We intend to continue monitoring this case, including geophysical investigations, remote-sensing based analysis of temperature anomalies near surface and gas compositional measurements, attractive approaches to investigate underground spontaneous coal-fires from the surface, and to enable a practical application based on the following simple reaction model:

coal waste + water + oxygen → solid products + gas products + heat

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