Exploring Arsenic danger awareness in the Polish Copper Basin – simulation of engagement in online networking

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Abstract

Aim. In cases of environmental danger, the information spread plays an important role in risk management. We have considered recent arsenic environmental danger in Głogów and Legnica (Copper/Cuprum Basin) according to the available data (2015-2017) from social network analysis and agent-based modelling point of view.

Thesis. In case of danger of unknown consequences, there are at least two different strategies of information management:
1) information spread that leads to awareness of the whole society;
2) keeping the whole information in secret under control that leads to a partial social awareness, available to a small number of people only.

Methods. In our model, the probability of information spread between two nodes is inverse proportion to connectivity of the susceptible node because people who have a lot of connections are more immune. We have applied theoretical agent-based modelling on Barabasi-Albert networks to explore various scenarios of information spread in Social Media. We have investigated the function of hubs within that concept.

Results. We have considered various levels of environmental danger and draw possible projections for the future. Oscillations according to temporal socio-political conditions as well as increase in attention in 2018 have been revealed.

Conclusions. Despite blocking of information by hubs, the successful information spread is possible when levels of danger are high enough. The perception and impression of information spread by society is also discussed.

Key words: Social Media, Environmental Awareness, Social Simulations

Arsenic in Cuprum Basin

Arsenic as a substance is very dangerous for health including a carcinogenic effect on the human body. It has been used as a poison and is based on a long history of alchemy [Fig. 1]. It causes the development of skin tumours and lung and liver damage. It may result in skin lesions, such as actinic pigmentation and inflammation.

Fig. 1. Arsenic: a mystic substance which was used as a poison when served or polluted water. Source: adopted from pictures from www.shutterstock.com.

We apply our investigation methods to the Cuprum Basin which contains Głogów, Legnica, Polkowice and Lubin counties in the south-west Poland. The cities of Głogów and Legnica are situated in southwestern Poland (Lower Silesian Voivodeship) next to 2 copper smelters (owned by KGHM) and contain around 100-200,000 citizens.

Arsenic is a natural by-product in cuprum plants and it is emitted to the air naturally [Fig. 2 left] in the investigated region. There are some restrictions in the European Union (even though there is no evidence in scientific literature) in quantities of arsenic concentrations in the air (6 nanogram per cubic meter). KGHM runs currently only one ironworks (copper smelter) in Głogów, and the second in Legnica has been shut down already. Some part of arsenic concentration in the air is emitted by KGHM, but the recent proportion is unknown. The company itself confessed their impact on 30% level, but it is probably underestimated, because closure of single smelter around Autumn 2017 in Głogów decreased concentration of arsenic significantly [Fig. 3 left].

Fig. 2. CUPRUM – Blessing (Salaries) or Curse (Arsenic). Left: Natural concentration of Arsenic in the air, Source: www.miedziowe.pl. Central: Cuprum Symbol and Logo of KGHM –the company mining cuprum, Source: www.holopatia.blogspot.com, www.kghm.pl. Right: Average salaries in Polish counties, Source: www.sztychawdane.pl].

According to the Provincial Environmental Protection Inspectorate, the arsenic level in Głogów and Legnica areas exceed a few times above the norm (measurement has been performed since February 2015).

Air pollution is a complex problem, but it delivers a strong proof of negative consequences on health by Particulate matter (PM 10 and 2.5), Carbon monoxide, Ozone, Nitrogen dioxide, Sulphur dioxide (HackAir, 2018). Air pollution could be a major risk on people's health as it may in long-term provoke the development or aggravate asthma and other respiratory diseases, heart disease and lung cancer, cause stroke and even shorten life span (HackAir, 2018).

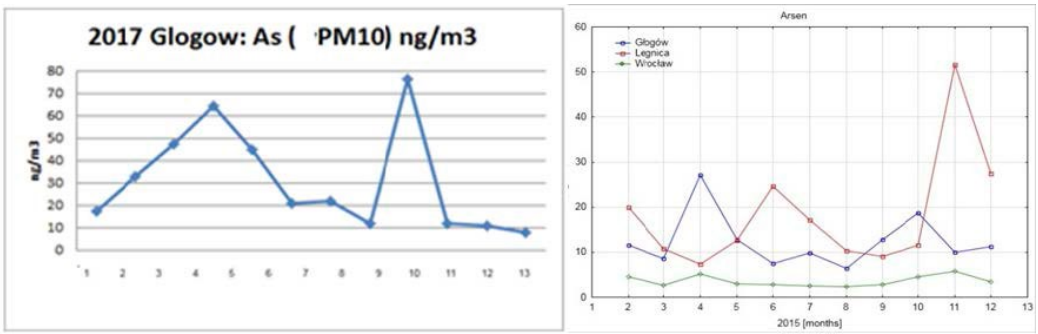

Fig. 3. Arsenic level in Głogów and Legnica in comparison with the capital of Lower Silesia Region – Wrocław, where EU norm is 6ng/m^3. Source: Own graphs based on data from Voivodeship Directory of Environment in Wrocław.

Perception of the risk is an even more complex problem, because the sphere of facts is combined with people's feelings. Arsenic in water is considered an important risk factor for many diseases. However, properties of Arsenic in the air at lower level as in occupational studies (Environment Agency England, 2008) are still discursive and there is:

- no scientific evidence on health effects;
- no standard methodology in epidemiological studies;
- no standards for measuring its assimilation patterns (hair, blood, urine).

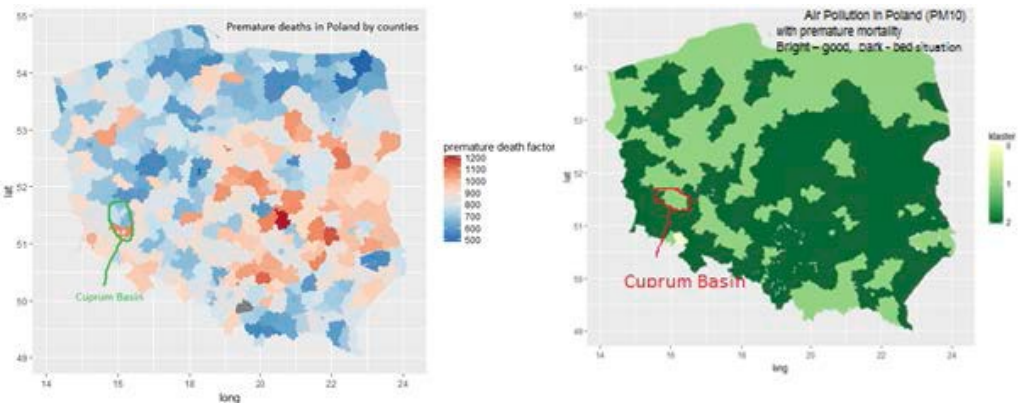

Fig. 4. [Left] Premature death index (more blue signifies less premature deaths). [Right] Quality of health with air pollutions (brighter implies better quality). Source: Own graphs based on data from the National Health Institute and the National Directory of Environment.

The link between Arsenic concentration in the air (exceeding the norms few times [Fig. 3]) and health is still unrevealed, despite people in Cuprum Basin living longer [Fig. 4 left] in better health conditions [Fig. 4 right] than the rest of Polish society. Occupational exposure of high dosage of Arsenic in the air could be linked to cardiovascular diseases (Environment Agency England, 2008), however mortality rate in 2012 due to Cardiovascular diseases in Cuprum Basin (330) is lower than Polish average (401) and much lower than in Lower Silesia (458). If there is a health effect of still much smaller dosage of arsenic exposure, it may be specific to some diseases (we do not have access to all disease registry) or it may be hidden by high incomes of Cuprum Basin citizens (wealth has a positive impact on health). On the other hand, Paweł Chruszcz (the member of Głogów City Council) had access to public health data that significantly exceeded average values in the arsenic danger area. Unfortunately,

Chruszcz died in May 2018 in unexplained circumstances. Current innovative diagnostic screening study shows slightly increased concentration of Arsenic in urine in sample of 1993 citizens of Glogow, but no statistics has been provided as work is still in progress (IMP, 2018).

Concluding background information: the necessity of scientific evidence that arsenic in the air has influence on health of Cuprum Basin residents still exists. The confirmed effects of other forms of arsenic pollution are, however, a cause for people's fears and beliefs, which are the main topic of our investigation. This simulation model of environmental awareness propagation is worth investigation because of lack of register-based data sets and relevant structural marketing purposes (Jarynowski, et al., 2015).

Social movements and social network analysis of environmental awareness

The social world deals, in particular, with connected systems endowed with network structures. Such a network is a subject to a certain structure which is often not known to agencies building it. Since the appearance of the interdisciplinary perspective known as Social Network Analysis (Jarynowski, 2014), the number of researchers in the social and behavioural sciences who are familiar with graph theory language, algorithms and theorems has been systematically growing. In network terminology for environmental issues, we can define:

- Node = individual components of a network (agent) e.g. Local media, Policy Makers, Activist, Pollution Emittents;
- Edge = indirect link between components (referred in social networking as a relationship between two agents);
- Path = route taken across components to connect two nodes (it is a very important issue, where we are looking at influential spreaders) important in flow of information in a network.

We have chosen random scale free (B-A) topology of the network. By using Barabasi-Albert (B-A) network, we input the existence of the most important agents as hubs - the most direct connections in the network, making it the most active node in the network.

Following a discussion of few formal approaches to interacting systems with focus on the social change, we present the sociological terminology and a few theories. In social sciences, there are three possible ways of explaining the success and failure of social movements: through the development of potent master frames and how they may be rendered impotent by sociopolitical changes; the presence/absence of societal strain, sometimes caused by economic hardships and relative deprivation, which may result in waves of social protest; and through the expansion or contraction of political opportunities such as the level of trust in established political institutions (Rydgen, 2005).

Critical phenomena in social movements is also a significant field of qualitative research. On the other hand, the knowledge about critical phenomena in economy is based on time series and correlations between assets. Thus, there are many other helpful tools including life-time of correlations or the Hurst exponent (Buda, Jarynowski, 2011) that may be extended to description and predictions of environmental phenomena (for instance: the Nile river behaviour). In our research, we focus on agent-based modelling applied to social networks, i.e. an explanation of using the terminology borrowed from the epidemiological modelling (Anderson & May, 1992) and innovation diffusion (Rogers, 2015).

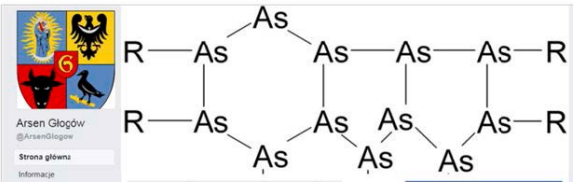

Fig. 5. Examples of Internet 'agents'-players of Arsen awareness on Facebook. Source: Facebook accounts (PawelChruszczGlogow, ArsenGlogow, 43domforfreedom)

Collective awareness of air pollution (Hackair, 2018) is a form of social movement. Currently social media and Internet can provide local communities with improved information about air pollution levels where they live and its impact on their lives. Air pollution [Fig. 6], and more specifically particulate matter, shortens people's lifespan and contributes to serious illnesses such as heart disease, respiratory problems and cancer (Fellermann, 2017). People engaging in online networking tend to gravitate to groups agreeing with their own views and listen to authorities which can be network hub of bridge. Users may apply the Internet websites for social movement building because of the

expected benefit and favourable circumstances (Szmigielska, et al., 2012). Most potential spreaders can generate or support movements, with the debate that it is able to create (Di Sia, 2017). These debates are often generated by content hosted on a blog or even more often on social media as Twitter or Facebook [Fig. 5]. Common knowledge (understanding common goals as environment) is a necessary condition for undertaking collective actions. Revolutions start when there is a large disparity between expectations and capabilities to satisfy them.

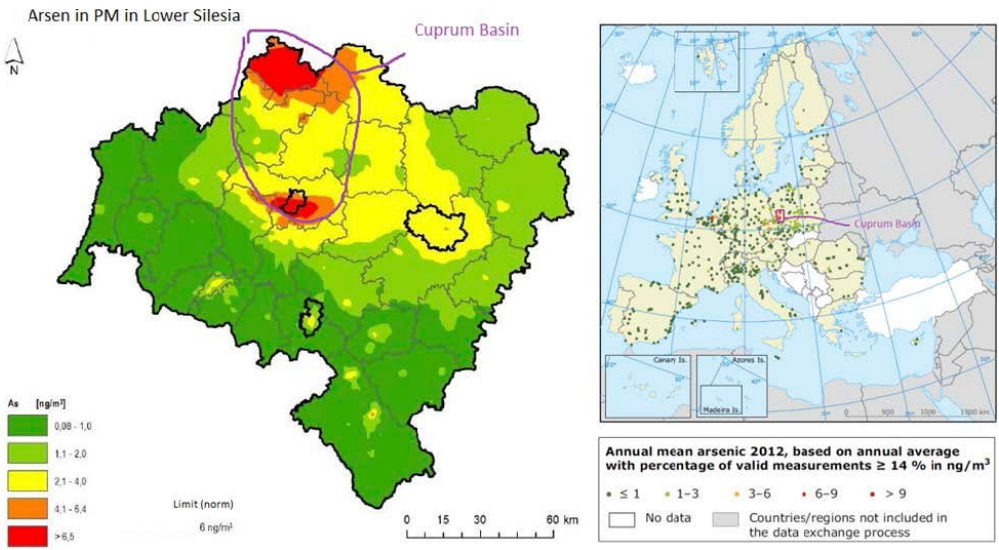

Fig. 6. Arsenic density estimation. Left: Cuprum Basin and Lower Silesia [Source: Adopted from (Voivodeship Directory of Environment in Wrocław, 2017]. Right: Europe [Source: Adopted from EA, 2014]

Techniques for quantitatively measuring topics discussed formation and evolution in social media is topic modelling (Gliwa, et al., 2013), where "topic" is a set of words that tend to co-occur in multiple blogs, posts or messages. Topic exploitation for a given group, defined as a ratio between number of group messages on a certain topic and all messages, could be also a measure of arsenic danger popularity.

Before we consider the Głogów case, let us show two more famous examples of air pollution cases from Easter Europe: Kraków and Chernobyl.

Air Pollution and ban for solid fuels in Kraków

Air pollution in Kraków poses a significant danger to human health and life [Fig. 7]. Kraków is ranked among the top 10 most polluted cities in the European Union in many dimensions. The best known and most common pollution measures (PM-10 and PM-2.5) have been informed to the public and digested by the public, because it has been linked with significant health problems. Around 90% of Europeans living in cities are exposed to levels of PM deemed damaging to human health (Hackair, 2018) and Kraków was leading most of the rankings. Through the years (2012-2017) public opinion appears to have mobilised by "Krakowski Alarm Smogowy" – a social movement fighting with pollution emitters. The success of this movement is a combination of successful spread of viral information (mostly in social media) and governmental substitutes fuelling the process. New technologies as the Internet of Things and mobile app play a big role in this social movement.

Fig. 7. Illustration of social engagement in Krakowski Alarm Smogowy. Source: based on pictures from www.krakowskialarmsmogowy.pl

In the Kraków case, the social engagement is slowly increasing and reaching the state [Fig. 8 Kraków] when democratic government must act (Ball, 2004).

Chernobyl disaster and the spiral of silence

After the Chernobyl Nuclear Power Plant catastrophe, Soviet Authorities declined to admit that the huge radioactive release could badly affect millions of people in Europe. On April 28th, 1986 The Soviet TV "Wremia" journalists made a comment "The effects of the accident are being remedied." The information spread was stopped at the beginning and no assistance had been provided for citizens of Communist Countries until the Western authorities spread the knowledge using their own channels of propaganda. It remained difficult for citizens to assess their exposure to radioactivity in the air in the Communist Countries.

Here, Soviets threatened "informed" individuals with isolation with slow increases of awareness in society at the beginning [Fig. 8 Chernobyl]. Thus, the majority opinion that there is no risk seemed to be more supported than it was in reality. At the last stage, the spiral broke, when Soviets could not hide the problem anymore, because of its tremendous effect (Noelle-Neumann, 1974).

We claim that network hubs are extremely important in broadcasting information and in essence of environmental issues, which are usually against spreading the knowledge because of incentives to keep it secret.

Model description

It is also relevant to give a sneak preview of an epidemiologic model of information spread, based on scale-free network. Each of the local actors is represented by a node with number of connections proportional to the size (importance) of a local actor (Castells, 2011). The total number of nodes in the Głogów network has been normalized to be around 100 (corresponding to number of local political parties, governmental bodies, industrial companies, media, health and environmental institutions, NGO and social activists, etc.). We could define virus as information that affects one actor after another (Leskovec, et al., 2007). Firstly, we choose a node as a source of infection randomly. Then, propagation branching process have been proposed according to SIS (susceptible – infectious – susceptible) model (Jarynowski, Grabowski, 2015).

The probability of affecting the nearest neighbours is proportional to:

1) a - the aggressiveness of danger (transmission rate per step or per month);

2) k - number of infected neighbours after every consecutive step (k is also inversely proportional to the total number of nearest neighbours). This imposes that hubs are more immune than the rest of society.
3) m - the life time of infection for a node (in steps or months) as a parameter associated with local discourse and level of environmental danger.

If we consider the local scene of government, journalist, activist as well as pollution producers, we can settle m between 2 and 12 months, because in each step agents can decide if they engage in action and share their opinion to their nearest neighbours next month. So, this minimum innovation diffusion step takes 2 months. It is clearly visible that aggressiveness of information must be efficient enough to infect the whole society.

Aggressiveness a could be settled between 0.1 and 0.9. It drives the sharpness of evolution (from smooth changes to abrupt transition).

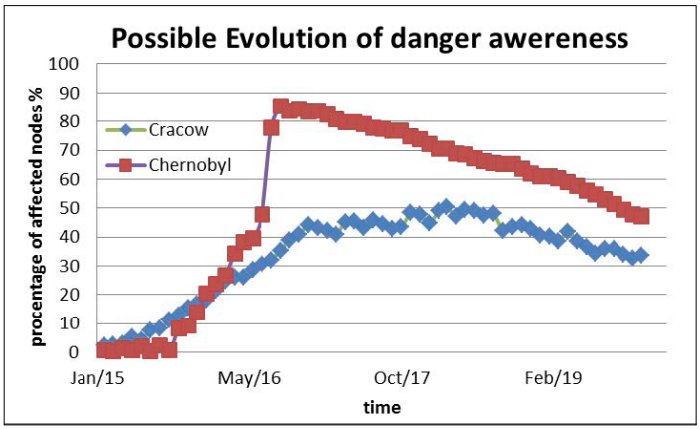

Fig. 8. The percentage of affected nodes in Głogów network as a result of simulation in: **Chernobyl like** scenario (high a - aggressiveness), in **Cracow like** scenario (high m - time endearment). Source: Own projections.

On the other hand, many processes need building into social movements and that needs much more time. Thus, it is reasonable to consider m bigger than 10. The epidemic could spread easily to all other nodes, but slower [Fig. 8 Kraków]. Our aim in future works is to consider more complicated networks and modern marketing strategies (with or without medial support) applied to local scene. Of course, keeping the nodes of local authorities in a state of affecting for m bigger than 10 extends story life-cycles, but it involves more costs and the return in various diffusion scenarios may not be optimal for social movements. On the other hand, medial support (increase in m) is more

than just the economy. It gives a benefit because all stages of product life-cycles are extended.

We have additionally incorporated an external field to the model such as regional elections, national mass media influence and ongoing reports from investigators. It was imputed as a point affection of random nodes.

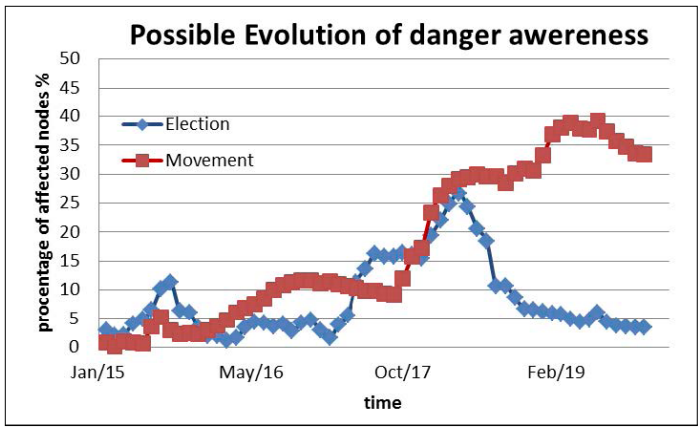

Fig. 9. The percentage of affected nodes in Głogów network as a result of simulation in: **Social Movement scenario**, where Moderate aggressiveness (a) and upper-middle lifetime (m) are efficient enough to infect most of the nodes in 4 years. **Election scenario** - however, if the danger has lower-middle (a) and moderate lifetime (m), the spread of popularity will decay completely shortly after municipality election in 2018. [Own projections]

Conclusions and further work

Lack of solid scientific investigations on arsenic air pollution with known arsenic poisoning properties in contaminated water can be the basis for people's fears and actions. Theoretic agent-based model of a social media system was introduced. According to a few simulation scenarios, we try to predict that percentage of actors involved in social media in the Cuprum Basin arsenic danger:

- Have been oscillating according to temporal socio-political conditions [Fig. 9]
- Will increase in 2018 [Fig. 9 Movement]
- Could be less and less in 2019, after regional voting in 2018 [Fig. 9 Election]

The Arsenic issue, however, is the main topic in local news because people are more and more aware [Fig. 9 movement]. Thus, few alternative scenarios are also possible, which are equivalent to perturbation in model parameters a and m. For example, any new knowledge or prejudgements could change parameter a (aggressiveness). On the other hand, building a strong social movement could increase m (time endearment), while social benefits and bribes from KGHM could decrease it. However, in the present "Internet Era," it is impossible to hide information to such an extend as was possible in the "Analog Era" [Fig. 8 Chernobyl].

Moreover, there is still no scientific evidence in the literature as well in publicly available regional data that arsenic in the air has any effect on the health of Cuprum Basin residents. The only solution for this problem is a proper medical investigation, which will bring in all the community, including The KGHM Company (Zbieg, et al., 2016). Mass media and scientists must investigate the impact of arsenic danger in the Cuprum Basin and medical knowledge could drive dynamics in social media to fuel the awareness [Fig. 9 Movement] or cause extinction of the topic [Fig. 9 Election].

Thus, according to our predictions, the average number of infected nodes of this social network is going to decrease fast after solving the problem. The unexpected death of Paweł Chruszcz in May 2018 is a kind of critical phenomena (turbulence) and its influence on final results may be unpredictable. Our agent-based epidemiologic model of environmental awareness propagation is worth investigation because of lack of medical knowledge and availability of social sources. In our future work, we plan to extend our model to the health parameters of all citizens in Głogów according to the official medical base (with data from Narodowy Fundusz Zdrowia), which allows switching to a system dynamics paradigm (Jarynowski, 2014). Topic modelling should also be used to reveal most popular topics discussed in local social media as well as position and evolution of "Arsenic Danger" there (Jarynowski, et al., 2016). Also, the source of the pollution may be detected by spatial distribution of citizen's diseases and simulations would not be needed anymore.

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