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When the red mud cleans capitalism by accident

Scientific researches on the bauxite residue and its utilisation in Hungary

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Abstract

It has almost been 10 years that the eco-social disaster of the red mud spill occurred in North-Western Hungary, near Ajka in 2010 on 4th of October. Since then, fish scientists, bioengineers, chemical engineers and bauxite technologists are jointly arguing for various possible forms of valorisation of the bauxite residue on the global market as a potential technoscientific solution for industrial waste management. This direction is the industrial waste research have been blossoming since the Hungarian red mud accident. This thesis, explores the way in which recently emerged scientific labour and knowledge production develop potential technoscientific processes in order to reuse the bauxite residue, in public imagination better known as red mud. To recycle the red sludge in a diversified way, alumina industry players prefer to categorise it as by-product rather than industrial waste. What is at stake in the growing red mud research is the classification of the matter as by-products which allows companies to treat the bauxite residue as a marketable product rather than a potentially harmful waste. In this thesis, I offer an ontologically flat analysis which looks at the matter's molecular interactions. By this, I show how unexpected entanglements of the red mud with other organic matters and living beings, such as water, soil microbes, earth worms and fishes, reveals myriad biochemical interactions which can be both deadly and beneficial for living-organisms in nature. However, as the red mud is also the repository of valuable components such as the rare earth element, such as scandium, it became locus of global competition between the EU and China. I argue that the case of the red mud demonstrates that recognising agency of microscopic elements in nature is twofold: it fosters a self-cleaning nature argument which might not think about latency in an invisible chemical infrastructure, and it contributes to further economic value extraction in global capitalist production under the disguise of zero-waste economy.

Keywords

Toxicity, biochemical becoming, by-product, industrial waste, agency, temporality, latency, clean capitalism

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'No one insists more on hygiene than the chemist in the laboratory and the surgeon in the operating theatre. Thus it seems that at least in practice, if not in theory, dirt and soiling exist even for the scientist. The requirement of cleanliness is already implicit in the requirements of chemical analysis.'

Olli Lagerspetz (2018: 71)

'Would-be green capitalism is nothing but a publicity stunt, a label for the purpose of selling a commodity, or – in the best of cases – a local initiative equivalent to a drop of water on the arid soil of the capitalist desert.'

Michael Löwy (2005: 19)

Introduction: Competing episteme of the red mud

Hungary has three Alumina refineries, Mosonmagyaróvár, Almásfüzitő and Ajka producing industrial waste which has become known as the red mud. The highly alkaline material was kept in the reservoir pods across the country as the wieldy used Bayer process by-product was a massive waterish body. On the 4th of October in 2010 near Ajka, without any precedent, the wall of the pond no. 10 broke though and the waste material spill invaded the surrounding villages of Kolontár, Devecser, Somlóvásárhely and Tüskevár (KSH 2010). Given the unexpectedness of the immediate eco-social harm, the Prime Minister, Viktor Orbán immediately declared a state of emergency and named it as 'ecological catastrophe' (BBC News 2010). In this thesis, I explore how the red mud accident was socially constructed and scientifically researched since 2010. As a Hungarian, knowing so little about the environmental consequence of the spill, I was curious to understand what the red mud is exactly and how scientists think of it in Hungary ten years after the catastrophe, and in what way technoscientific researchers contributing to the recycling of the red mud.

Constructing toxicity

Shortly after the red mud spill, the National Directorate General for Disaster Management (NDGDM), functioning under the Ministry of the Interior, publically shared its data revealing the components of the red mud such as mercury and radioactive elements. It has been a crucial moment in understanding the way in which the red mud has been interpreted and portrayed in the global media since that day. A free-lance bauxite technologist and the representative chemist from Greenpeace I interviewed critiqued the information the Hungarian authorities officially published. They remembered it did not reveal the greatest source of harm, the pH of 13, at the time of the spill. Mercury and the radioactive elements were not compounds of the sludge which would have rendered it a toxic matter. They even saved a print-screen of the website to keep the obviously misleading list of data in their Ajka folder. The following day, scientific data was replaced by update corrected ones, leaving the mercury out from the story. Although the correction happened, the bauxite technologist was not satisfied: 'It spread like a forest fire. Afterwards, you cannot correct the misleading information. Even the biggest industry players still refrain from recommending the sludge to farmers for agricultural purposes. Since they might read about it. They do not want conflict, thus it rather remained accepted as a banned material.'

What the global audience came to know about the red mud was that it entered into deadly and damaging interaction with all what stood in its way on the day of the accident. Ten people died and many were injured due to the acid composition of the bauxite residue. Livelihood of local villagers and small businesses were damaged, local food production was banned and water reserves were contaminated with alkaline and metal residues – as the online press noted (Kenarov 2011). The total fish population in Marcal River completely perished. As one of the fish scientists told me, only a leech survived the unfortunate spill. But this creature was removed from the river, captured and placed in formalin, and then shipped to a research institution to commemorate its miraculous survival.

By circulating satellite photos representing the massive mud-like currents flooding the neighbouring villages, Ajka deserved to be named as the first, unprecedentedly occurred red mud accident's location (Gelencsér et al. 2011). For Hungarians, like myself, it became a memorable event, a year marking the unforgettable date of a disaster the whole nation collectively experienced. I remember even the smallest villages got mobilised and managed to raise money for the victims. Some rather decided to go there and volunteered for the cleaning process. Due to the media representation and international broadcasting, the red mud was inscribed in the collective memory as a toxic waste material. Therefore, the name red mud does not trigger more in popular imaginary beyond the warning sign of its redness. The mere geographical closeness to Ajka was also perceived as a risk-factor. For instance, 'Somló mountain wine production came to a halt' due to the circulated news about ecological catastrophe, although the wine fields were not physically effected (Jávor and Hargitai 2011: 145). This examples shows that the governmental discourse supported by misleading data, the online press and the sudden deadly and damaging effect of the red mud jointly formed a popular knowledge about the red mud's materiality. This constructed images had further material effect on scientific knowledge production I discuss in this thesis.

From the red marks to the laboratory

What most of the Hungarians came to uncover about the red mud after the accident was that it was a toxic material long dormant in dams built near the refinery. The massive liquid form of the red mud broke through the dam near Ajka recolouring the surrounding villages. Most of the Hungarian scientists I talked to were sent to the location on the day of the accident, and participated in the remediation process. They jointly noted that the iron rich material marked trees, plants, concrete buildings, humans and animal with its redness. Nevertheless the red mud, due to the rainy weather and its liquid structure, penetrated into soils and rivers with ease. Water sources further mixed and carried the red sludge to other rivers up until it jointed the Danube. Due to the waste material's colour, as a bioengineer shared with me, in contrast to colourless industrial waste, her research team could easily detect and followed its way to spot the critical points of contamination.

Figure 1. Kolontár (2018.11.22.), photo by Alexandra Czeglédi

Almost ten years after the spill, when I visited Devecser and Kolontár, I was searching for red marks and lines on the walls in a similar vein as the scientist did on the day of the accident. Some residents repainted and renovated their homes. Others kept the stigmatising signs to not to forget about the industrial crime they were subjected to. Wondering around Kolontár, one might notice the victims' properties marked by blurry lines of the red mud, such as a reversal scene of the biblical pass-over. The red colour reminded me to dried blood which could not be the sign of passing over protected houses, on the contrary, it is rather the remnant of destruction. The colour of the red mud turned out to be important for several reason. Not only to spot the level of the sludge and spots it has effected, but for scientists who are in intimate connection with the matter through their laboratory labour, the colour is a telling property. It changes according to its locations and compounds.

A bioengineer from BME I interviewed noted that there is differences between German, Greek and Hungarian red mud when she looks at the samples. She showed me her pictures taken in the laboratory where bauxite residue samples organised in small size pots according to their colours. With this, she intended to demonstrate the most remarkable differences in colours which could be the easiest way to make me understand the chemical diversity red mud samples encapsulate. I swiftly came to learn from her that the residue's properties and potential effect of toxicity primarily depends on the 'original bauxite', storage technique and technological process it has been produced under.

Chemical engineers prefer to refrain from the popular appellation: the red mud. When I used this term instead of bauxite residue I was kindly corrected several times during our conversations, although, they kept using the red mud terminiology interchangably. Bauxite residue is the only correct description of the alumina by-product. It does not only sound more scientific for non-connoisseurs as I initially thought, but also reminds me of the importance of chemical components the residue consists of. The red mud can vary in terms of substances, microbial interactions, and consequently having different potentiality to do harm, and even good in interacting with living-organisms. The chemical actors are observed and manipulated first in the laboratory and then by technological process. By this terminological correction they draw my attention to the agentic capacity of molecules. However, understanding the components of the red mud and their effect on human, animals, plants and microbes remain dependent on the inhuman apparatus (Wark 2015) which is the technoscientific materialisation of scientific knowledge. This knowledge is deriving from the laboratory labour: testing different red mud samples and their capacity to interact with other molecules.

Although I was interested to hear about the materiality of the red mud itself, chemical engineers and bauxite technologists often talked about the red mud by comparing technologies and storage infrastructures in other cities and countries as well. Along the six interviews what I conducted at University of Miskolc (ME), Budapest University of Technology and Economics (BME) and at the Hungarian Academy of Sciences (MTA) and Greenpeace Hungary, it became clear that researchers understand Ajka's red mud materiality and reconstruct it from a global scientific perspective through knowledge and technological transfer which goes beyond the red mud accident. When I asked an open-question about the red mud, they often introduced the matter through their international network of scientists and research agendas. By talking about the red mud, they often referred to other researchers I should contact to find out more about the red mud. Through the snow-ball methodology, I contacted scientists who could frame the component, capability and potential usage of the red mud within their fields of soil science, fish monitoring, bauxite production and selective chemical technologies. Their global perspective and research agendas automatically revealed me that there are various zones of red mud samples collected from to produce a globally circulated knowledge.

From chemical molecules to infrastructure

Knowledge production about the bauxite residue has been little up until the Hungarian red accident occurred. Most of the scientists noted that their research agenda changed due to the red mud spill. Their research team was sent to Kolontár and Devecser to test the soil, water and fish. Comparing it to the main producers, the red mud production in Hungary has been marginal. But Ajka's red mud were named as the first disaster without precedent, as a bauxite technologist reminded me, despite that sporadic leaking and accidental spills obviously occurred before in India for instance. However, the unprecedentedly portrayed and framed ecological catastrophe grab the attention of scientists and alumina industry players.

After the industrial procedure, the red sludge's amount is approximately two times more than the highly valued aluminium itself. To express it in numbers, one can speak of 11 088. Thousand metric tonnes alumina which was legally produced across the globe (Word Aluminium 2018). The data equally indicate that alumina industry is certainly produced on each continent of the Globe. The red mud waste production chiefly takes place in countries such as the US, Brazil, Venezuela, France, Germany, Greece, Ukraine, Russia, China and Australia, to mention only few of the main industrial sites (Word Aluminium 2018). Industry players in these countries, especially in Greece, China and Russia, as scientists shared with me, are interested to know more about the red mud's molecular capacity to reuse it, and possible technological improvements in the sludge storage.

This cross-continental production of the bauxite residue and interest in knowledge production about the red mud allows me to understand it as a globally present hyperobject, rather than an isolated cases of industrial accidents which occurred in Hungary, and more recently in Brazil (2018). Timothy Morton (2013) calls the massively distributed quasi-objects on Planet Earth hyperobject, those substances which transcend the anthropocentric understanding of time-frame and space-sensing. That is, Morton touched upon the question of temporality and locality compressing the molecular and local into a global scale. I engaged with. Instead of looking at the red mud as a hazardous material in itself (Gille 2016), I propose to think of the bauxite residue, following scientists' thinking process, in terms of the constant biochemical becoming (Kirksey and Helmreich 2010) which occurs below the threshold of human perception, at molecular level (Morton 2013, Bennett 2010, Wark 2015) and enters into interaction with other living organisms. Biochemical components and microbes make integral parts of the social fabric, and therefore can be included in the anthropological fieldwork (Benezra et al. 2012).

The matter itself, kept in a reservoir with seepage, is interesting, as it gets better known through accidental, chemical interactions. Over time, a toxicologist can determine the form and the level of damage that toxic substances can cause in living organism. In long-run, the effect of toxicants might change through various biochemical exchanges and spread over one place to another (Davies 2018: 1538). These microscopic actions are invisibly, but latently, slowly but persistently exhibiting their effect in a chemical infrastructure. Biochemical becoming manifests for instance through bioaccumulation in water and food which further structure the future life of both human and non-human life, differently put, it has an effect on reproduction in a broader sense (Murphy 2013).

Scientists who shared their knowledge about that red mud with me often demarcated the limits of their knowledge on the list of components the matter consist of. In the red mud removal process, they often noted argued for a strong agency of nature. It has the capacity to self-clean and adopt hazardous molecules. They often pointed to the problematics that effects of certain elements are not yet researched or remained uninteresting for the alumina industry players and state-financed research committees to produce more laboratory testing in relation to the red mud's behaviour and potential usage in the near future. While some components and biochemical becoming of the red mud gained more financial support from companies and the EU.

Classification for recycling

However, scientists implement knowledge via non-human apparatus like microscopes, chemical test materials to test and better understand the matter and its entanglement with living and non-living organism for the moment being. While they are testing the components, they have a list with the legally accepted thresholds in Hungary consider. Scientists play a great part in setting up a threshold on what counts as danger and harm and what is acceptable substance mixing with living organisms. Although the category of harm, especially potential damage in relation to toxicants, which refers to the hazardous chemical materials produced via industrial processes. (Liboiron et al. 2018: 334) is highly contested and changing over time.

Measuring toxicity is a crucial in setting up categories which can be utilised in global capitalist production. Through defining toxicity, profit making and damage causing at play in industrial production (Liboiron 2018). What is at stake in the case of the red mud is the category of waste and that of by-product. When I asked scientists why it is important to define the category they told me that latter qualifies the red mud for further industrial process with a less strict regulations than in the case of waste products. Indeed, along the interviewing I got to know that the red mud is not necessary a toxic matter in small dosage. With both hazardous and beneficial effects it can exhibit, it qualifies as by-product. This category seems important for recycling technologies to be tested and implemented in harmony with the EU zero-waste directives.

Scientists I interviewed told me that almost ten years after the accident they still do not know what happened to the red mud which was removed from Devecser and Kolontár. According to a bioengineer's speculations, within ten years, it will be in demand to recycle it. 'It make sense, I see fantasy in recycling, and you can go far with this kind of research'- she noted. More recently, the hidden value in the bauxite residue (Liu and Naidu 2014), pointed out by most of the scientists I met, overlook the category of hazardous waste for the sake of profit making endeavour. The production of the red mud at massive scale evokes that the by-product of the mining industry is still a potentially marketable product almost everywhere in the globe, expect in costal countries where the red mud disposed into seas and oceans (Jávor and Hargitai 2011, Gille 2016). However, its commodification, inscribing value to the waste material, depends on investment in scientific knowledge production and its implementation via technoscientific apparatus which can enable scientists and engineers to withdraw rare earth elements from the red mud or optionally produce soil ameliorant out of the matter (Ujaczki et al. 2015).

This research, thus, wishes to reveal the way in which the complex materiality of the red mud, as biochemical becoming, via scientific knowledge production and labour, became a prospective object of inquiry triggering global technoscientific competition. Although, I prefer to argue for an ontological opening (de la Cadena, 2014) which means that I take the chemical and metal molecules of the red mud as actors with capacity to influence global politics, I could not leave the global industry actors out as scientists immediately connected their laboratory researches to industry players in terms of defining their interests in new technologies and financing their projects.

As one of the Hungarian scientists noted, it might be equivalent to very precious materials in the near future which will induces more competition amongst global actors for refining and recycling components of the red sludge through innovative techno-scientific procedures. In light of this, this research I discuss how the biochemical becoming of the red mud is politicised through technoscientific solutions tested in the alumina industry under label of greener, zero-waste economy of the EU. I show how the Hungarian red mud spill, the popular image of the red mud as toxicant and cost-benefit analysis of industrial players shapes the directions in the red mud research.

Chapter 1: 'Nature is strong enough to solve the red mud spill'

Fish scientists and bioengineers researching the soil looks at the red mud from a non-anthropocentric point of view, from an angle which decentre the human. That is, observing, measuring and testing the effect of the highly alkaline material's sudden entanglements with other-than-human-beings tell us more about the red mud itself. Thinking with nature, and of the way in which living-beings reacted to the red mud is worth to further discuss in order to understand how the red mud is subjected to scientific knowledge production. In so doing, I introduce the biochemical interactions the bauxite residue forged with fishes and microbes in the soil. Scientists and engineers who are long conducting research on soil, fishes and mineral compositions jointly argues that nature has the capacity to survive the moment of the red mud spill event. The ecosystem of soil and rivers are able to self-clean to the extent that animals and plants are back to the ecosystem near Ajka.

'Shock for human and non-human'

I travelled to Balaton, where fish researchers were conducting their fieldwork on fish populations. On the yard of the research institution, there were several boats, abandoned, seemingly unused. I noticed them when the fish scientist I first interviewed showed me around. One of the boat his research team used in the Marcal River testing after the red mud accident were still around, but kept in a garage. They rather not leave it out. It is a reminder for aftermath of the accident they witnessed in 2010. He said it kept the colour of the red mud they cannot vanish anymore, it embraced the iron oxides in way that that boat could not be cleaned properly, even when they have tried. Also, their measuring device got completely damaged to the extent to which it could not measure the PH level of the sludgy water of the Marcal. All these encounter he recalled was by thinking of his working tools, the boat and the device. The research trip to Marcal River in October 2010 was as much unexpected as the stubbornness of the colour imprinted in the boat. His research committee urgently allocated funds for testing the neighbouring rivers the next day after the accident. It was an opportunity not to miss, although they did not know what to expect from the sudden encounter of red mud in the rivers.

'What does not kill makes you stronger, but I am sure that nature could not adapt this man-made material fully'- as one of the fish scientists put it. 'It was a sock for everyone. All the fish population perished and our measuring devices were damaged.' He remembers when the red mud reached the Marcal and Torna rivers, which immediately got under the effect of PH of 13, exterminated the whole fish population. There was hardly anything to look up for in the red alkaline water which burned wholes on their protector equipment too. However, three days later, they could catch the first fishes swimming up to the Marcal's contaminated water. He said it was possible for living-beings to slowly repopulate because of the remediation process the Hungarian government launched immediately. They used gypsum from the neighbouring factory to neutralise the alkaline water which reduced the harmful effect of the red-pink water. His research team was monitoring the repopulation of the fishes in Marcal which occurred unexpectedly swiftly. Although, the water was still visibly contaminated one year after the accident, new fishes appeared, even those which were not endemic before.

Despite the blossoming repopulation, his research team did not recommended local businesses to allow fishing on the tested rivers. His colleague added that he personally could not eat from the fishes caught near Ajka. Given they did not tested the chemical effect of the red mud on water, they could not specify its aftereffect on fish population and water. According to him, metal parcels could not been mobilised in the highly alkaline water which was a good news for living-beings. They could not been effected, but he further speculated that via bioaccumulation of metals in flesh of the fishes, over time the red mud might reveal its negative effects. Uncertainty of this kind about the future of the Marcal in terms of accumulation of industrial derivatives shows how fish scientist think of latency which is crucial in dealing with industrial contaminations. Latency implies non-human temporality which thinks of long-term chemical entanglement to understand the red mud impact on water and fish population.

During the interview, fish scientists put a non-anthropocentric argument forward: 'If someone will go there in two thousand years and drill down, if there will be human at all, there certainly will be found traces of the red mud. But on evolutionary scale, it was only a flashing moment the nature will recover from if industrial wastes does not destroy it completely.' This argument reflects a non-anthropocentric thinking about nature by noticing that industrial production leaves traces behind as potential fossils for the future. It has the capacity to damage and destroy nature, but nature has the capacity to adopt and survive, more the human species. Nature of the future will be a hybrid one mixed with inorganic industrial materials. Paradoxically, the bauxite residue, deriving from mineral mining, after going through chemical treatment by technological apparatus, might be merged with nature in form of sediments and fossils by industrial mismanagements. It is similar to what Nils Budandt and Anna Tsing (2018) argued about species invading a post-industrial coal mining site and able to domesticate the human-made ruins. Similarly to fishes, weeds and microbes can be attracted to human disturbance (Ibid) what soil scientists noticed shortly after the red mud accident. The weed can take over the post-mining setting and live in contaminated soil.

Soil microbes welcomes the sludge

One of the bioengineers from BME who participated in the remediation process agreed to meet in a café in Budapest. She could not take me to her laboratory as she was on leave. She swiftly get into the lecturer position by enthusiastically talking about her research on risk assessment in contaminated soils near Ajka. Back then, she decided to study engineering in order to utilise her data to translate it though a technoscientific apparatus which can induce beneficial changes in nature. Being proud of her involvement in the red mud-related remediation research, her research team and she have noticed further possibilities in using the waste material for agricultural purposes following the remediation in Devecser and Kolontár.

Similarly to 46 studies published until 2016, her research team also concluded that there were no major hazard identified after the red mud spill in short term-assessment. But the highly caustic nature and fine particle size of the red mud negatively impacted the soil structure around the broken dam. Toxicological studies showed that the red mud in high dosage damaged the ecosystem of the soil, perishing earthworms and microscopic organisms. However, due to the remediation process, the contaminated soil was removed and rapid recovery was possible to witness (Mayes et al. 2016). She participated in the laboratory research which concluded that the soil touched by the red mud can get mixed without any problem up to 3-5 cm to avoid the costly soil replacement. Testing were done to find a cheaper solution for the cleaning process. She told me, it was possible to do so without any risk because the metal components were under the nationally set threshold, only the PH of 13 exhibited a risk factor. After the remediation process, they only find certain spots which was still contaminated.

More importantly, she noted that due to the laboratory testing they noticed that the soil even enjoys the iron rich red sludge up to 5% density which is able to boost microbial interactions. She said that 'the refined matter helped to restore the structure of the soil which could comfortably host bacteria, and live could be back again to the sandy soils. It contained calcium, phosphor and potassium which had beneficial effect on the soil.' Her research team started to apply their data and created a 'Red Mud Soil Mixture' (RMSM) in inhabited zones within Hungary. They merely applied it next to the highway and post-industrial, abandoned zones few times. The remediation project did not go popular. They have only received few opportunities to use the RMSM.

I asked her why it would not be possible to recycle their mixture in agriculture if it is proven beneficial to soil lacking nutrients. She asked me back: 'Who would be okay with a dosage of red mud in his/her back garden? From social perspective, it is not acceptable.' I was hesitating for a moment to agree with her. But indeed, as a

Hungarian, without knowing about the red mud's potential in detail, I might not be comfortable with buying a soil ameliorant substance to make my flower garden more fertile, blossoming by the support of industrial chemical. The red mud has a bad connotation in popular imaginary, but even among industry players, as I mentioned earlier. When I started off my research, I was pretty sure I will hear extensively about the matter as an unwanted by-product, toxic and useless for both human and non-human. When she opened her presentation to show her pictures, we stopped at the slide saying 'fear from the red colour'. Indeed, the almost omnipresent fear from the red sludge banished the possibility of recycling it in agriculture in Hungary. At best, the beneficial mixture find refuge in making highway sides more aesthetically pleasant, covering constructional ruins with red mud soil and green plants.

'It is not realistic to use the red mud for soil' – she added. 'It is possible to cure the soil system with mixtures like that, but they won't use Ajka's sludge for that purpose. It is owned by the Hungarian state, but I guess it will be bought up soon to coax the rare earth elements out.' These speculation shows that the valuable elements has more chance to be reused within the metal industry than remediating sandy soils with the red mud. I got to know from her and a bauxite technologist, that the beneficial usage of the red mud cannot be possible in the nearest future due to the mediated images and popular knowledge about the matter. Farmers, especially Hungarians might be openly against it. Although, it sounds as a viable technoscientific solution in making soil microbes more active for agricultural production, the long-term effect of contamination in soil were not tested by the bioengineer's research team. She added that she cannot predict it, but the soil samples surely shows that industrial activities contaminated the soil way before the red mud accident occurred near Ajka.

Latency of the chemical infrastructure near Ajka

Fish and soil researchers jointly noted the ability of nature to adapt and enter into biochemical interaction with the red mud. It might be deadly, slightly harmful and yet beneficial for other beings. These cases strongly stands for the agentic capacity of nature to deal with the red mud to certain extent, mostly in small dosage, after the alkaline layer were removed. Both informants agreed that they cannot predict the future effect of the red mud on nature, but certainly there were contamination way before the red mud spill near Ajka. When I interviewed of the representative of the Greenpeace, I got more answer about the risks that remained present around the alumina refinery.

Most of researchers shared their concerns about the metal components of the red mud infiltrating into drinking water and soil. The jointly negated the presence of mercury as one of the dangerous mobile metals. However, the Greenpeace kept monitoring and testing the water between 2012 and 2016 which accumulated arsenic, aluminium, phosphate, cyanide, ammonium and sodium. Amongst these components, the arsenic molecules deriving from the red mud posed a risk which might cause cancer over time by bioaccumulation (Greenpeace Hungary). As the chemist shared with me at his

Greenpeace office, most of these elements are mobile which might not cause major problem in the next five years. Measured data, conducted by most of the scientist across the country, were compared with the threshold set for sewage, that was the reason why the tests does not indicated sever contamination. In contrary to that, Greenpeace tested water and compared its components with threshold applied to drinking water. Arsenic compounds, in this case, were found hundred times more than it supposed to be, as there is no set threshold for this metal. He also noted that the thresholds are easy to play around with. 'If one does not want to show the contamination, it is possible to do so.'

What should be taken into consideration, beyond measuring and disproving toxicity with set threshold data, is the constant presence of contamination and presence of mobile metal compounds. 'If everyone do the same, after all, the effected places will be contaminated…. The best would if we could put an end to alumina production.' His research agenda and conclusion does recognised agency of nature in terms of coping with a certain level of toxicity, but he took temporality of chemical interaction into account. In contrast to other researches I was introduced to, Greenpeace envisages a nature-centred production system within which alumina production poses threat, and projecting hazardous materials into waters and soils. Moreover, his argument points toward the question of possible accumulation of different toxic materials in industrial landscapes like the one near Ajka. Fish and soil scientist also noted that chemical contamination was already present, before the red mud spill. It is worth noticing that different temporalities are at stake in evaluating the red mud's effect.

Thinking through temporalities, a non-anthropocentric one, we arrive to the concept of latency. Michelle Murphy (2013) argues that instead of the suddenness of contamination, we should pay attention to the slowness of bioaccumulation of chemical components in nature. One cannot think of contamination as a singular event, but rather as a chemical infrastructure constantly reproduced threatening reproduction of future life and conditions to live. It might invisible and imperceptible, but over time, in mundane acts it reveal itself. By breathing, smelling, drinking, one can form a knowledge about the latently present chemical infrastructure. Latency is important to note according to her, as there is temporal gap in chemical exposure and experiential symptoms (Ibid). In this sense, the red mud is merely one example for the biochemical becoming within a broader chemical infrastructure.

While Greenpeace draw attention to the temporality and latency in contaminations. Nature might be strong for a moment being but the accumulation of various industrial by-products on peripheral lands of industrial activities like the one near Ajka can lead to a greater damage, and reproduction of harm over time. It might be exhibited and noticed only by the following generations which has already been sacrificed by the crisis-solving approach of scientists. Although all of them expressed uncertainty about the future, as one of the chemical engineer expressed it: 'there is no reason to be afraid of the red mud.' It might be true that the red mud alone does not mean danger, but thinking about the uncertainty and latency of the chemical infrastructure it is part of, take us beyond the problem of the red mud accident.

Nature is not a closed ecosystem indifferent to industrial interventions. What we simply call nature is a fabric of 'communicative interactions' which has long been mediated by chemicals (Eisner 2003) at microscopic level. It is able to adopt abandoned ruinations from where industrial interests withdraw (Tsing 2015, Bubandt and Tsing 2018). Fish and soil scientists are researching the red mud's effect on different ecosystems. One might say that there might not be a difference in how the red mud produces effect, makes novel and harmful entanglement in nature at molecular level. However, in post-industrial waters and soils, than in laboratory the red mud has various faces to show us. Fish and soil scientist revels two ways of biochemical becoming of the red mud: the devastating chemical sludge and beneficial microbe-activator.

These scientific narratives about the red mud destabilise its classification as hazardous waste, and interrogate the normative understanding of living and dying with industrial waste materials. It this sense, nature is entangled with human activities and dynamically changes with it, rather than being the passive receiver of toxicants. Through bioaccumulation and molecular changes, the red mud get missed with other metal components and living-organism within a slightly perceptible chemical infrastructure supplied by industrial actors near Ajka.

Chapter 2: Scientific paradigm shift due to red mud spill

The red mud accident, with the label of the very first industrial accident of this kind, gained great visibility drawing attention to the researches conducting about Ajka's red mud. If one type the key word of 'red mud' in Google search, the first pictures one comes across are undoubtedly depicting the bauxite residue spill mostly effecting Devecser and Kolontár. The exact moment of the spill from the pod no. 10, taken from a bird's eye view, most probably the first one came to notice. The red mud accident has globally been identified with the Hungary. 'Paradoxically, the story of Ajka is the one which became public. In the case of the Indian red mud spill, the owner had an interest in not to make it public. Some sludge drained out of the dam, but they managed to patch it' – said the bauxite technologist. He also noted that although he was not an expert on the red mud, he became one of them.

Online press like the CNN, BBC and the Hungarian media contacted him to find out more about the potentiality of the bauxite residue. The socially constructed fame of Ajka's red mud along the competing narratives and speculation about the accident circumstances lead to a 'paradigm shift', as he put it, in technoscientific knowledge production in relation to the red mud. As Zsuzsa Gille (2016: 84) has indicated already, the aftermath events of the spill forged a loose network of red mud researchers, an epistemic community in the Hungarian natural science circle. This accidental, rather intentional shift, brought professional acknowledgment, international publishing and funding opportunity to the post-socialist research hub.

Multiple actors at play

The allegedly red mud as toxicant has already been considered to be hazardous given the positionality of the dam, the pod no. 10's closeness to neighbouring villages (Gille 2016: 78-81). The bauxite technologist noted that the amount of the red sludge in the reservoir were augmenting in the pod no. 10 for several reasons. First, it was the heavy rain and windy weather influenced the moment of the approximately 1 million cubic metre sludge (Greenpeace Hungary) weakening the dam's structure. Secondly, engineers allowed to build the pond in question out of recycled industrial waste of the grey sludge which back than seemed suitable for this purpose. Thirdly, he noted that the engineered infrastructure of the whole pod no. 10 was questionable.

The documents and data he came across and analysed was serving the MAL Ltd. to prove its non-culpability in front of the court in 2018. 'It confirmed that the engineered structure could take extra 50% load of sludge. This detailed calculation were approved by local environmental authorities for many years. I would show you this document but strangely it is still in the grey zone of public and non-public accessibility. I would say the whole structure and location of the pond was under-engineered in 1989.' At that time, shortly before the privatization, the alumina factory was still a state-owned infrastructure originally inaugurated in 1942 (Gille 2016). The state did not urged either the transition to the dry stacking technology despite, as he noted, that it was an available technology from the 1980s. He told me it was only introduced in the Soviet Union and China, in newly inaugurated refineries which were recycling the waste sludge making cement out of it, almost without further remaining waste.

To make it more understandable for me he put it in the following way: 'If you buy a car, and you find all details fine, you are not going to go back to the producers to complain about the engineering mistake if you have an accident.' His argumentation seemed to defend the MAL Ltd. from being the only responsible actor in making the red mud sludge spill possible near Ajka, but he also acknowledged its objective responsibility. 'It is right, but there were serious engineering mistakes way before the MAL Ltd. bought the refinery up.' By his illustrative example, he showed me that red mud spill could happened due to the interplay of different actors across time, with an emphasis on poor infrastructural planning. He added that there were no legal constrain which could urge the MAL Ltd. to implement the filtering technology as it was the case in Mosonmogyoróvár' refinery. The dry stacking technology was only implemented after the accident which produced, a more preferable 'semi-dry cow faeces' form which could not necessary mean a hazard. But he added that 'the social effect were more or less unconsidered in continuing the dry red mud production. The dry material were still spread by the wind, so the refinery has to be closed down.'

A potential hazard was always been there since the establishment of the alumina refinery near Ajka which was not taken seriously neither by the Hungarian state during state socialism, nor did MAL Ltd. do initiatives to satisfy the residents' need after the privatization. Scientific data analysis and his professional experiences I was told about by the bauxite technologist shows that accumulated effects of poor engineering, local environmental authorities' corruption, and the heavy rainy weather culminated in the unfortunate event which was named the first, unprecedented red mud accident. The red mud spill brought natural scientists attention to the red mud they barely or hardly knew about before. He became one of the expert on the red mud, although he was trained and specialised in how to make aluminium out of the mined bauxite.

As my informant further put it, the accident was indeed unfortunate as it caused death and damages, but worth noting that sporadic seepages near dams are natural. 'For instance, in India there was already a red mud spill accident at a refinery he visited. There were enough industrial interest and little media attention to not to name it the very first accident. Further to that, seepage was almost always present in the Indian case as well. It seems it almost impossible to keep the red mud away from getting in contact with the soil. However, these similar cases and seepages has occurred which constantly, effect the nature, undoubtedly latently. By acknowledging this technological shortcoming in landlocked industrial waste management, he also pointed toward the existence of the almost invisible, but constantly nurtured chemical infrastructure reproduced by the wet red mud technologies. Furthermore, in engineer circles, improvement in the technoscientific apparatus in treating the red mud become more striving agenda.

Out of the 'dead valley' by technological innovation

'Do you know what is the dead valley effect?' - the bioengineer affiliated with BME asked me. I could not even guess what she referred to by this metaphor, than she continued: 'It is when a researcher does something, the results re good, but it does not going to be applied. I studied engineering to apply my founding and see them working in real life.' She participated in the soil remediation project near Ajka which allowed her to have an insight how to bring changes on the ground on the basis of laboratory research. After they were in the field collecting soil samples, British scientists contacted her research team. 'The alkaline waste material is not very researched. The British geologists got interested as they were publishing a lot about that before.' Due to that internationally recognised research teams got in touch with, she emphasised that her department's positionality in the global scientific network has changed since the red mud accident. 'In the aftermath of the accident, more publications came out indicating that the red mud is present in an great amount across the globe and it would be good to recycle it. Before that, we were a small research team in Hungary, but today, we got recognition. It was difficult to publish in international journals, but I do it for ten years now. The accident was a beneficial reference that we should take care of the storage problem and recycle it because it contains many precious metals.'

Similarly, the fish scientist from MTA noted that they were not specialist of the red mud, but after the accident they could publish in international journal. His colleague even changed his research topic and included the red mud accident in his Phd dissertation as a case study. Although they published their data at MTA, their recommendation on restructuring the Marcal river's bed did not received founding. As one of them noted, there were more interest in fish colonisation for business purposes rather than enabling a rich ecosystem in the Marcal. They noted that no one contacted them to implement their plans according to their calculation, even if they have produced data 'for free' for industrial players, founded by the Hungarian government.

The bauxite technologist I talked to similarly argued that he noticed a change in the direction of ongoing research and patents implemented in pilot stages concerning the red mud utilisation. When he applied for conferences with his research and patent plans on the alumina production, his Chinese, Brazilian and Indian colleagues invited him to rather give a speech about the red mud accident. 'Greek researchers contacted me and I supervised many Phd project since then. If I go for a conference, in five minutes I find common acquaintances with anyone. At best, they even came across my publication.' The main research focus in relation to the red mud, what he got engaged with as well, is how it is possible to utilise the bauxite residue. The wet technology's major disadvantage that there is a massive amount of liquid produced. 'There are competing technologies. The direction in research is going toward extracting rare earth elements form the red mud. It was rare when someone researched them as it is impossible to see them with the naked eye. It is still little in the bauxite residue, but not trivial to coax them.'

The red mud accident and accumulated knowledge production, even when scientists I interviews were not interested in the industrial waste before, were encouraged by the accessibility of the filed. The data what they gathered after the accident enabled them to publish in internationally recognised journals. The fame of the red mud and global scientific curiosity offered opportunity to some Hungarian engineers to take their research further. Fish scientists from the MTA are do not working toward materialising their research. The bioengineer form BME was smiling when I mentioned the institution. She noted that they have merely been producing data but not looking for technical solution as engineers does, to find financed projects, and by this way, their way out of the dead valley of data accumulation.

Looking for the precious elements in the red mud

When I arrived to University of Miskolc, a chemical engineer received me in the building. He suggested to sit down somewhere in the laboratory which is more convenient environment than his messy office. He rather did not offer me a place there as the laboratory is cleaner. The scientific environment turned out to be more convenient where we had a morning coffee accompanied with test tubes and the red mud itself. He asked me whether I saw a dose of red mud before. I told him about my visit in Devecser and Kolontár where I was looking for the remnant of the red mud on the building's wall. He was smiling and cheerfully went to look for the dried material. In few minutes, he got back with a small ceramic pot of bauxite residue putting it next to my coffee. I was reluctant to touch it. 'There is nothing to be afraid of' – he said. It seemed to be an innocent matter, although after experiments in the laboratory, it recolours the equipment and tables. 'Scientists do not like it due its persistent colour.' And he immediately wanted to demonstrate the both friendliness and stubbornness of the matter. He went to wash it under the running tap water when I took several picture.

Figure 2. In the laboratory of the University of Miskolc (07.06.2019), photo by Alexandra Czeglédi

By introducing me to the matter itself, as lecturer in position for many years, he intended to educate me about the red mud. To better understand the technologies and ongoing researchers about the utilisation of the red mud, it might be useful to touch and smell it before one comes up with a conclusion about its toxicity. The sample he washed in his hand left traces on his skin. 'Do you see that it is difficult to get rid of it?' Given the very fine powder-like matter, it was challenging to imagine it actually contains multiple chemical compounds. Most interestingly, something precious can come out of it which can be valorised on the global market. I only saw dirty dust running out from his hand.

When I asked him about the components he knew in the red mud, he walked to the periodic table. I made a common non-connoisseur mistake by asking about the heavy metal components of the sample he showed me. 'It does not contain heavy metal, but rare earth elements.' It makes a difference, as I learned along my research, as the rare earth elements (REE) are so little in the red mud that it does not cause any harm in contrast to the heavy metal compounds like mercury which could be more like a working sign. After a short introduction into metal elements, he showed me the bottom set of elements in the periodic table which are worth keeping. Some of them such as scandium, gadolinium, and cerium sounded familiar from my previous interviews. 'They are rare not because of they are so little on Earth. They can be found everywhere, but they are rare because their concentration in one place is little. That is why it is difficult to extract them.'

The red mud seemed important in his laboratory environment because, as he noted, chemical engineers can test and coax the rare earth elements. Even before the accident, he published his laboratory testing results about the utilisation of the red mud. He run a research project on how to selectively unlink mineral elements from the rest of the red mud's components. Chemical technics are at help to take certain elements out. 'But we do not know where exactly the rare earth elements are, there is not that sensitive analytical tools to detect their forms. Although the iron components are difficult to separate in a way that does not damage the rare earth elements, big projects can be launched in this field these days.'

In the laboratory, by closely look at the red mud collected after the accident I came to understand that it is not a static, easily identifiable material, rather a mixture of many, often unknown but valuable elements scientists are trying to better understand, extract from the liquid matter. The chemical engineer at University of Miskolc were not involved in any projects about the red mud research, but he noted he used to experiment with it. We tried to apply the chemical techniques he familiar with on the red mud. He also acknowledged that the bauxite residue become more interesting matter after the accident although he knew about its potentialities before, and saw the valuable elements in it.

Chemical techniques are at stake in the red mud research. It is an experimenting process, looking for something we knew about, but still does not process the knowledge to extract the valuable elements. By adding chemical components to the red mud, one might sit and wait for the result. External molecules, such as bacteria and water, become translated and absorbed within the molecular structure of the metal as well. Metals, contrary to the commonsensical knowledge, are not fixed objects as we frequently perceive them. Rather, they are fluid matters which slowly and profoundly flow at molecular level. In so doing, they are able to grasp other molecules and to render these external components into internal ones (Barry 2010: 92-94).

Molecular fluidity within the red mud poses a challenge in translating the scientific knowledge into technological patent. Into an apparatus, which translate human-made knowledge into preferable action at molecular level, either to make cement, colouring materials or to extract the rare earth elements. Conceptually, these many, still unknown elements are present in the red mud which can be utilised, especially the scandium seemed to be one of the microscopic entity which recently deserved more attention within the European Union's projects. The bioengineer I interviewed and her research team at BME got involved in one of these with their research agenda, due to their experience with the red mud. 'This is the new direction with the attempt of diversify the utilisation of the red mud. In order to utilise it, it should be a by-product rather than a waste material.'- she told me before started to teach me about the scandium recycling project.

Chapter 3: Global competition through molecular commodification

What is at stake in the case of the red mud utilisation research after the infamous spill is the category of waste and that of by-product. When I asked scientists why it is important to define the category they told me that latter qualifies the red mud for further industrial process with a less strict regulations than in the case of waste products. Indeed, along the interviewing process I got to know that the red mud is not necessary a toxic matter in small dosage. It was even demonstrated in the laboratory where I can touch the dry matter. That is, toxicity is not an objective fact commonly acknowledged by scientist and settled by scientific research on determining an objective threshold as I illustrated above.

I argue what is at stake in negotiating classification is the allegedly eco-conscious red mud storage and utilisation technologies replacing the Best Available Technology which is still the wet Bayer process (Gille 2016) as the bauxite technologist also shared with me. The recognition of by-product category at EU level is important, namely for a Greek alumina company, in order to get financial support for technoscientific researches on utilisation and thus valorisation of the red mud's rare earth elements. The European Union finances research projects under the directives of zero-waste economy, for instance one on scandium extraction from red mud as a promising valorisation technological innovation. Scandium is not only valuable element, but also rare within the EU, while China has access to rare earth elements and able to export them. 'But this is politics, and we are scientists'- as one of the bioengineers from BME reminded me when I asked her more about the global power-game around scandium. Departing from the molecular becoming of the red mud, we swiftly arrived to the global competitors for valorisation.

Politics of classification: waste or by-product

Naming the red mud as industrial waste does not trigger much in public discussion. The category of toxicant or toxic sludge, as the global media often referred to (Williams 2014), leave the categorisation untouched. According to the chemical engineer at the University of Miskolc, there should be only one threshold system set for one category, regardless of waste and by-product, to measure the level of toxicity. However, politics is at play in categorisation. The epistemic framing of the red mud is at stake in fitting in one of the definitions.

Zsuzsa Gille (2016: 76) noted the importance of categorical treatment in the case of Ajka's red mud. When the Hungarian government adopted the EU waste classification, it created a loophole which allowed the alumina refinery, the MAL Ltd. to classify its bauxite residue as an intermediary material at the so-called production site. According to her, it was a self-regulation from the company's side. Instead of a name it as waste disposal site, the ponds were registered as technological facilities. She speculated this happened because that the owners of the alumina refinery planned to recover precious rare earth elements from the red mud to gain more profit out of the alumina production. Russian and German companies planned to remove the sludge which would have been beneficial for local environmental remediation (Ibid: 83). However, it is worth noting that the Hungarian classification of intermediary material leaves room for valorisation initiatives. Buying up the red mud and further testing it required a by-product category, as the bioengineer from BME noted which could contribute to further innovation in remediation research.

With both a hazardous and beneficial effects, what the red mud can exhibit, it qualifies to be a by-product. This category seems important for recycling technologies to be tested and implemented in harmony with the EU zero-waste directives. According to the EU commission, a by-product is only a suggested, non-binding category which refers to an industrial material with the potential of having various impacts on the environment (European Commission, Directives 2016). In this sense, as Zsuzsa Gille aloo argued, recycling might be partial solution for local environment. The red mud was proven, through its biochemical becoming, hazardous as a liquid and beneficial soil ameliorant in small dosage. As a waste category, recycling and phasing out the non-recyclable materials would be an objective (General Union Environment Action Programme to 2020, 2013). Recycling and reusing of the red mud, since the spill, has been novel direction in technoscientific knowledge production, due to the attention what the red mud globally received after the accident.

According to the BME-based bioengineer's speculations, within ten years, the red mud will be in demand to recycle it. 'It make sense, I see fantasy in recycling, and you can go far with this kind of research.' She also acknowledged that there is different regulation for waste and by-product, but she could not share the concerns that the red mud was under consideration for rare earth elements extraction. It might simply the case that MAL Ltd. did not wanted to apply the waste disposal regulations. Further to that, the technology for recycling was not available. Moreover, what the bauxite technologist shared about the poor engineering planning and construction, the classification would not have improved the circumstances of pod no. 10 near Ajka. What is more important to note here is that the by-product categorisation got politicised exactly for the sake of both recycling and profit making out of scandium. Extracting scandium from the red mud seems even more beneficial as it would be an alternative replacement material of aluminium. Paradoxically, a substitute of the metal the red mud derives from.

Scandium: zero-waste economy camouflages competition

'The European union finances applied researches. At our university, there are two ongoing projects within the framework of Horizon 2020. One of them is the SCALE, the European metallurgical by-product project.' The bioengineer from BME proudly shared with me that she is part of the EU-funded international project. For her, it is an opportunity to do beneficial research which might bring changes in the alumina industry and at the same time do good for the nature. 'The Greek alumina industry wants classify the red mud as by-product, but it is a EU-level game. This is also falls into the interest of the European Union within the circular economy, to recycle all.'

Figure 3. SCALE, Scandium Aluminium Europe

On the webpage of the scandium extraction SCALE project, research institutions, including the Hungarian BME and alumina companies promise a zero-waste process to the EU Commission. The dynamic promotion video goes further, and envisions a cleaning chemical engineering process in the laboratory where the waste material transformed into treasure of the future. It does not only openly allures the economic profit, but also offer the possibility of getting rid of the industrial waste material. By this futuristic ambitions, the research team seems to cancel out the category of waste and replace it with not merely a by-product but with a valuable material, the scandium (SCALE 2017-18).

The EU Commission's directives suggest an imagined zero-waste economy, a circular economy expanded within the economic zone of the Union. It support exactly what alumina industry players promotes in the SCALE project that 'Europe can benefit economically and environmentally from making better use of those resources' (Towards a circular economy: A zero waste programme for Europe).The recycling of the red mud seems to be fitting in what EU directive imagined. This research platform was initiated by Aluminium of Greece because 'it is financially beneficial for them' – said the bioengineer from BME. 'They have their own bauxite mining field and they are owning the whole technological infrastructure of the production, the full value chain. It is a zero-waste project, but I am not sure they will managed it'. She was sceptical to acknowledge the possibility for waste-free utilisation of the red mud. 'Exciting and risky properties coexist. One can use the residue after the extracting the scandium but probably it cannot be fully implemented.'

Along the interview, I got interested in the history of the scandium. She was enthusiastic to talk about what she called 'the higher-level game' of classification of the red mud. The green side of the scandium treasure history is covered, circulated at EU level. Sustainable growth is an EU directive which environ a better, eco-friendly economy. However, as she shared with me, the scandium is not merely an expensive rare earth element, but is also on the list of the EU's supply risk. In 2017, the scandium, partly due to the Greek industrial lobby, appeared on the list of critical raw materials (CRMs). The justification for it is the economical need and the raw material utilisation in clean technologies like 'electric vehicles, solar panels and energy-efficient lightning' (European Commission, Internal Market, Industry, Entrepreneurship and SMEs). Cleaning Europe with economically beneficial production constitute an image what the European Union projects. 'It is absolutely a new trend'- she added.

Without even going further on the supply risk track, the bioengineer told me she travelled to China several times to conferences. 'The Chinese also got interested in recycling technologies. They realised their profit-oriented industry destroyed their environment, and by that, the future of their own children. China extract rare earth elements, including scandium. There is a supply risk with the EU since it is dependent on Chinese import. There is a competition for keeping the scandium production within the EU. It is possible to extract it from other sources than the red mud, but the EU cannot mine it.' Her insight into EU-China scandium supply politics was possible through her involvement in the red mud research. She got started her scientific carrier as soil expert in remediation process, but by now, she is proudly taking part in the competition-induced red mud recycling research on scandium. 'The Chinese wants to learn from the EU, but it might be the other way around' – she noted.

Extracting the scandium from the bauxite residue might be the first step in clean the alumina industry's technoscientific infrastructure in the future. However, the chemical hunt for the treasure is not necessary motivated by getting rid of industrial waste material such as the red mud. Rather, her ongoing research reveals that competition for scandium on the global market is not secondary justification to finance the vision of zero-waste circular economy within the EU.

Diversifying technologies and cleaning zones

The red mud recycling is a striving research filed. 'It can be used for soil, mixed with cement or coaxing valuable elements out of the sludge. My colleague conducts her research on gallium extraction. The elements are in bulk in the red mud, therefore we have to diversify the recycling processes.' Diversification argument in the red mud recycling show how broad is the industrial interest in making profit with reducing the waste material. The bioengineer and bauxite technologist jointly noted that it is almost impossible to recycle all components of the red mud. 80% of utilisation might be possible with advanced technologies what can be improved with further innovative techniques. In research agendas valorisation also got more attention than the full-scale recycling (Mayes at al. 2016). The bioengineer form the BME told that although rare earth elements received greater attentions, the radioactive comments of the red mud has not been often tested. 'It is a sensitive topic in research'-she said.

As the bauxite technologist noted that he is up to register his patent and convince a Brazilian company to install his technological innovation which would recycle most of red mud. However, the more common wet Bayer process and dry technology is 'Best Available Technology' (BET). This has almost always been determined on the basis of a cost-benefit analysis taking the greatest profit into account in implementing the full technological process (Liboiron et al. 2018) in alumina refineries. In the case of the Brazilian refinery, the representative of the company were reluctant to implement the Hungarian bauxite technologist patent, despite the pressure to make their technologies green, especially after the Hungarian (2010) and Brazilian (2018) red mud spills.

He noted that these industry players does not see the long-term benefits of greener and more profitable technological patent he offered to them. 'They simply do not want to take risk and invest in new technologies.' He acknowledged it is obviously not without risk, as someone can fail with calculating every moment of the production. One calculation mistake, or unconsidered circumstance can bankrupt companies. 'It happened in Japan when a Japanese researcher stole and tried to implement my patent, but he failed. To utilise the red mud, there is approximately 1200 patent from which about 100 became pilot projects. This research envy shows that there are competing technoscientific solution to clean the alumina industry, in a way that preferably makes profit to the refinery.

When the cleaning technology also fails to work, and get public attention, as it happened in the case of the post-accident refinery near Ajka, the global supply chain connections are at work. He told me he participated in the planning of the alumina refinery in Bosnia Herzegovina which now supplies the aluminium producer in Hungary. Outsourcing the bauxite refining, in theory, solved the problem of the red mud shortage near Ajka. However, what one might not see from viewing the red mud through the Hungarian locals' eye is the global network within the latent chemical infrastructure. The post-industrial zone of Ajka might be cleaned through remediation and constant measuring through samples, but a chemical infrastructure has been reproduced by outsourcing the production and the waste shortage. But does the clean technology offer a solution for the red mud-problem?

I argue that greening of the red sludge via laboratory research and technological innovation might be beneficial. However, there is an attempt to extract further value and marketable rare earth elements from the red mud and waste is still produced through the extraction process. As scientists noted, it is almost impossible to fully reuse the red mud, only few percentage is possible to be valorise in forms of a product like soil ameliorant, cement, colouring material etc. It is also worth noticing, that within the diversification attempts, there is economic competition, social pressure, geo-political preferences at play in which technoscientific apparatus get funding. Thinking of the marginal soil ameliorant utilisation of the red mud and juxtaposing it scandium recycling, one might better illustrate the priority of competition over greening. What is beneficial for microbes in soils might not be economically justified as cleaning scandium project. That is to say, technoscientific researches and suggested solutions for the red mud are highly politicized and hijacked by global economic interest.

Conclusion: Cleaning capitalism by accident

The case of the red mud spill near Ajka draws attention to recognition of the agency of non-human molecules in nature emphasised by researchers and engineers I met. They often rehearsed that nature is strong enough to deal with mere flashing momentum of the red mud spill in the evolutionary history of the environment. Through molecular interaction, biochemical becoming the red mud has multiple after-life and metamorphosis via natural phenomenon (soil ameliorant) or technoscientific intervention in the laboratory (scandium extraction).

Scientists researching the red mud and their narrations shows that they see possible ways out from the contaminated post-industrial landscapes. Biochemical adaptation of the uncanny material of the bauxite residue in nature, which could not leave its traces behind without human-designed technoscientific industrial regimes, might be called a hybrid biochemical prospecting, excavating information out of mixing of organic and non-organic matters to utilise it for agricultural purposes. Chemical prospecting usually refers to utilising natural components found in nature without human intervention (Eisner 2003). It the case of the red mud, the prospecting is working as a process, because there is an accident-induced scientific competition for coaxing various elements out of the matter. Its refined materiality does not make scientists' task easy. Making treasure out of the waste, I argue, is hybrid prospecting which capitalise on agency of nature.

The agency of nature argument, I argue, does not necessarily serve the non-anthropocentric vision about the future in which human recognise that they should respectfully share the Planet Earth with other beings. Capacity of nature in coping with toxicants and inorganic materials, on the contrary, provides a justification for scientists and industry players to ignore the long-term effect of contamination. Understanding the feral dynamics of nature (Bubandt and Tsing 2018) might be utilised as an argument to ignore the latently present chemical infrastructure partly composed and reproduced by mining industry. If one argues that nature is able to solve and take over ruined places, scientists might be attentive to the extent that via biochemical prospecting they utilise the knowledge of microbial actions, such as it happened in the case of the soil ameliorant. Finding solution for contaminated zones is a patching of the invisible chemical infrastructure through the knowledge produced due to the red mud accident.

Also, acknowledging the agentic capacity of nature in terms of having capacity for self-cleaning further minimises harm it is subjected to, and consequently justify further possibilities for human-made biochemical interventions. But most importantly, it justifies the cheapest and BAT infrastructure the corporate profit making is relying on. A cost-benefit analysis of profit making is the economic principle (Liboiron et al. 2018) what the EU managed to combine with an environmental-friendly discourse. I discussed above the EU attempts to greenwash and clean capitalist production with the red mud recycling.

That is, capitalism is reproduced by accident, there is a competition within the post-accident red mud research for the sake of cleaning the alumina industry. I argue what is worth noticing in the red mud's case is not only what is beneficial for the environment and for profit but rather that capitalist investments in allegedly zero-waste technologies serves as justification for maintaining their global industrial status-quo through competition. Global capitalist production, thus, solves its own problems through investments in scientific knowledge production, with attempts of greening its technoscientific regimes instead of reducing alumina production. Even with the EU-founded scandium project, the replacement of the aluminium appears as an illusion of cleaner future while million tones of red mud still produced. Science makes innovations, adjustments out of accidents and problems it faces, revisiting the technoscientific knowledge accordingly (Beck 1992). Thus, the inhuman apparatus produced by human labour reveal a certain power-knowledge if one look closer. In light of this, I suggest to take the inhuman apparatus seriously (Wark 2015) as I showed it in the red mud's case, in a multi-material ethnography.

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