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Technologies and transformations. Traces from a collective research project

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Abstract

Artisanal and small-scale gold mining in the Democratic Republic of Congo (DRC) is undergoing rapid and profound changes, moving from a predominantly manual to a more heavily mechanised form of production. The articles in this special issue collectively aim to understand these recent transformations and their impact on labour, productivity, taxation, health, and environment. They are the result of a collective research project carried out in the two largest mines of South Kivu Province by a multidisciplinary team of anthropologists, biologists, economists and medical doctors. In this introduction, we first of all present a deep reflection on the research *process*, including questions about power and ethics. We then reflect upon the empirical and theoretical contributions to emerge from the six papers that make up this special issue, which centre around the three major drivers of recent ASGM transformations: 1) technological innovation and adaptation, 2) capital investment and 3) socio-political reorganization. Finally, we highlight how humans and nature are transformed in the process.

1. A starting point

April 2021. After ten years, I find myself back in Kamituga, the gold mining town where I observed for the very first time how muscled young men descend into the depths of dark and dank tunnels to come back with bulky bags of sand. Where I first smelled the fumes of nitric acid burning on a metal spoon. Where my feet first touched, and slithered, the slimy tawny mud. Where I - young, female, white, middle-class, ignorant PhD student – recorded my first interviews, the clangorous sound of a pestle hitting the hard rock as an eternal background sound. Today, the sound is different. Mortar and pestle have been replaced by mechanized ball mills. They are loud, they produce a lot of dust, and they grind hundreds of kilogrammes of rocks per day (first author).

In the past decade, artisanal and small-scale gold mining (ASGM) in Eastern Democratic Republic of Congo (DRC) has undergone a profound transformation. This transformation is the result of technological innovations and adaptations, capital investment, and socio-political reorganization. This process has by no means been different from other gold producing regions in the world (Verbrugge and Geenen, 2020). In fact, DRC can be considered as a latecomer to the process of economic upgrading in ASGM. In countries such as the Philippines (Verbrugge, 2014), Indonesia (Verbrugge et al, 2021), Peru (Cortés-McPherson, 2019), Colombia (Robles Mengoa & Uran, 2020), Ghana (Crawford & Botchwey, 2016), Guinea (Dessertine, 2016) or Burkina Faso (Lanzano, 2020), the use of large excavators, mechanized ball mills, metal detectors and cyanide was already widespread more than a decade ago.

The technological ‘deepening’ – the intensification of resource extraction through technological innovations and increased inputs – and geographical ‘widening’ of ASGM has been explained by Verbrugge and Geenen (2019) as a response to three major limitations facing global gold production. First, by allowing to mine deeper and access previously inaccessible deposits and by enabling renewed

processing of tailings, it provides a solution to the problem of scarcity. Second, by relying on cheap, flexible labour and remaining informal, it can operate at lower costs. Third, being more in tune with local socio-political and land tenure systems, ASGM may be seen as a more legitimate alternative to large-scale mining.

As a consequence, while remaining largely informal, ASGM has moved beyond subsistence in many areas around the world. It has now become the domain of capital investors – some of which are domestic, some of which are foreign, as for instance in the increased worldwide presence of Chinese small-scale operators. At the other end, the workforce is extremely diversified, composed of trained mining engineers to female stone pickers. In this special issue we document the drivers of these technological transformations as well as their consequences in terms of work regimes, productivity, health and environmental impact.

The debate on ASGM in the DRC has focused a lot on mining reforms and formalization, in a context of international regulation around “conflict minerals” and ineffective state regulation. In previous issues of this journal, authors such as Iguma Wakenge et al. (2021) and Vogel et al. (2018) have documented the ambiguous outcomes of mining reforms at the local level. Artisanal and small-scale mining has long been marginalized and portrayed in a negative light because of its informality. The plurality of legal regimes fuels conflicts between ASM and large-scale mining (Geenen, 2015; Huggins, 2022; Katz-Lavigne, 2019). Although artisanal mining zones have been demarcated and mining cooperatives have been created, these have not contributed to improved living and working conditions in the mining sites. Mining cooperatives have been critically analysed as instruments for elite capture (De Haan and Geenen, 2016) that risk to further marginalize the most vulnerable mine workers, including women (Bashwira and Cuvelier, 2019; Furniss, 2022; Kamundala, 2020). In brief, mining reforms result in hybrid governance outcomes at the local level, with historical continuities in terms of local elites controlling land, labour and capital (Geenen and Cuvelier, 2019). Yet recent governance shifts towards “responsible sourcing” have pushed some companies and international organizations to engage more directly with mine workers “on the ground” (Deberdt and La Billon, 2021), and the Congolese state to create a state-owned company with a monopoly on the purchase of cobalt (Deberdt, 2021).

As such, the Extractive Industries and Society has promoted a rich debate on ASGM governance in the DRC. However, in the past ten years, the sector has not only witnessed governance shifts. One development that has long remained under the radar, is the introduction and adaptation of new technologies. It occurred gradually over the past ten years, but has suddenly become very visible in the presence of machinery, the scaling up of ASGM activities, and the presence of small-scale companies, many of which are Chinese. This special issue contributes to understanding these recent transformations, connecting to debates on technological innovation and adaptation. It does so on the basis of data collected in two mining sites in South Kivu province, which is a small illustrative sample of ASGM in the DRC. Methodologically, this special issue is unique as it is the result of a collective research project. In the next section, we first expand on the *process* of doing research, including ethical reflections around collaboration.

2. A research process

On a personal level, this project has further developed the urge in me to do research. It has helped me to work more as a team, and this teamwork has increased my performance and motivated me to respect deadlines. Especially the exchanges we had every evening, while being in the field, inspired in me the spirit of listening and taking into account the opinions of each. It also fostered my sense of curiosity, as new ideas came to my mind in every discussion (one of the contributors to this special issue).

This special issue is the product of two research projects, and a team of fourteen researchers. The first project is part of a research programme entitled Winners and Losers from Globalization and Market Integration, funded by the Research Foundation Flanders (FWO) and the National Foundation for Scientific Research (FNRS) through its EOS programme (G056718N). A sub-project under the coordination of Sara Geenen focuses on technological change in artisanal and small-scale mining. The second is a project on health and environment in ASGM, funded by the Global Minds programme of the Flemish Interuniversity Council (VLIR-UOS) through the University of Antwerp in Belgium. This action research project aims not only to understand the health and environmental situation in the mines, but also to propose and communicate best practices to miners and policymakers through sensitization.

In the DRC, both projects are coordinated by the Expertise Center on Mining Governance (CEGEMI) at the Catholic University of Bukavu (UCB). CEGEMI was created in 2011, as part of an institutional collaboration between the UCB and Flemish universities. It was set up as a multidisciplinary research center and now brings together more than 30 academics doing research on natural resources. Ten of the contributing authors to this special issue are members of CEGEMI. Ten of them are based in Bukavu. Eleven of them had previous research experience in the mining areas that have been included. As such, this research is part of a wider and institutional effort at promoting *multidisciplinary and multi-method academic* research driven by *Congolese* researchers.

The initial motivation and justification of this effort was very much to stress the value of long-term engagement and gradual build-up of expertise, in response to the ‘helicopter’ and demand-driven research initiated by numerous international organizations working in and on the region, and beyond. The initiators were responding to the call by Olivier de Sardan (2011) to “get rid of the perverse effects of consultancy to leave a specific space for genuine research”. It quickly turned out, however, that without any structural funding – neither from ‘Northern’ academic partners, nor from in-country scientific funds – CEGEMI would need to enter the battlefield of the ‘international consultancy market’. Still, so far the center has succeeded in promoting a lot of academic research that is not demand-driven, but rather responding to the needs and challenges around the region’s natural resources identified by Congolese themselves.

The two projects on technologies and health and environment were initiated by Sara Geenen, the coordinator. They were designed as separate projects, but gradually came to overlap and partly merge. For the technologies project, a team of experienced researchers and specialists was brought together, with diverse disciplinary backgrounds in development studies, anthropology, economics, biodiversity, biology and engineering. They were all asked to define a research question within the broader theme of ‘technologies’, which led to a collection of abstracts covering angles from productivity to socio-technical systems. Next, the team collectively worked on a series of interview guides, adapted to different categories of stakeholders. All team members added some interview questions relating to their proposed topic. As for the health and environment project, this team included more experienced researchers as well as less experienced ones (about half/half), including medical doctors, agronomists and economists. Here, the coaching by the more experienced team members was more intensive and an online methodological training session was organized before starting to design the methods. Each team member again gave input to the interview guides, focus group guides and participatory methods, and finally the data collection tasks were distributed among all team members, taking into account their strengths and fields of interest. In March 2021, the coordinator decided to organize a joint field visit for data collection. The reasons were partly pragmatic (more cost efficient), but it also became more and more clear that the research results from both projects would be mutually reinforcing.

Eleven team members participated in a first research visit to Kamituga, which lasted for one to two weeks (two for the technologies project, one for the health and environment project) in April 2021. As one of the contributing authors expressed in the opening quote of this section, the field visit was inspiring. Above all, there was a strong team spirit with ample room for stories and laughter, which – we may assume – was motivating for all. The debriefing sessions at dusk provided space to discuss methods, sampling, findings and interpretations, and to collectively adjust sampling strategies or interview questions along the way. On the last day, the photographer accompanying us brilliantly captured this team spirit (see fig. 1). Unfortunately, the one team member in charge of logistics and finance – and hence without any doubt the one that was bearing most of the stress during the entire trip – was absent when this picture was taken – which more or less proves the point that he probably carried the largest burden. Later that year the picture was selected by the donor as one of the 20 ‘best’ pictures of 2021, leading the coordinator to tweet that this made her prouder than publishing a paper.

Fig. 1. The ‘winning picture’. One team member – the one in charge of logistics – is not in the picture. The photographer – not a contributing author to this special issue – is.



Source: Robert Carrubba

I propose that we improve on the aspect of compensation to the interviewees (buying juice and biscuits for them) and reduce the time of the interviews, because most of them had to work and we were taking a lot of time from them (one of the contributors to this special issue).

But behind this successful, joyful façade, carrying out this research was also tough. The living and working conditions in the mines are notably difficult. Being confronted with this reality comes with a lot of discomfort, particularly when trying to manage the expectations that interviewees have of the presence of the research team. This discomfort is shared, but at the same time very different across age, gender, race, and personality. Asking interviewees for their time can require a lot of courage, knowing that you are intruding in people’s life and work spaces, while they have a thousand more

pressing needs than to participate in a research project. Explaining the objectives of the research and repeatedly justifying its added value can be exhausting. Fortunately we could draw on prior contacts to ease access.

During our first stay in Kamituga, we organized two public information sessions to communicate the results of previous CEGEMI research. We had printed and brought with us a lot of publications, which we tried to strategically distribute to key stakeholders to demonstrate reciprocity and so that they could further communicate our work to others. This was important to show CEGEMI's commitment to the topics and the research area. However, such efforts are not sufficient. Only a limited number of people were able to attend the information sessions, the publications were in French (the official language, not the locally spoken language), and not in an appropriate format (academic output). In addition to research, the health and environment project also includes a second part: sensitization. However, this part has been delayed because towards late 2021, the team members spent a lot of time producing the academic papers. The academic papers (French working papers and the articles in this special issue) were planned as an output in the technologies project, but not in the health and environment project. Along the way though, the idea emerged to add two papers on health and environment, which disrupted the initial schedule. In particular, due to time constraints, the project coordinator could not manage both the writing and the sensitization. The consequence is that the sensitization has been extended to 2022, with implications for the demands that are made on the team members – they also have to prolong their availability for the project.

In May 2021, the 'technologies team' continued the research in Misisi, for a period of two weeks. The security situation in Misisi is more volatile than Kamituga, and the road to get there is also much longer and more insecure. The 'health and environment team' did a follow-up visit of another week in Kamituga, in August 2021. During that time, they were able to follow up on some questions that had emerged in the first phase of data analysis.

Apart from our strong motivation to do research, the payment we received was an important motivation, but when there are delays – mainly because of administrative hassle – the team becomes less efficient and the work suffers (one of the contributors to this special issue).

All team members have academic or research ambitions and considered this project to be a good opportunity to build up their experience and their CV. Still, several team members already had first-hand experience of the structural exclusion of Congolese academics and researchers from the international academic market (see Marchais et al, 2020: 382). Most have only had short-term contracts with Congolese universities or higher education institutes, or short-term projects funded by international NGOs. These precarious working conditions force researchers into a vulnerable position with very little room to negotiate contracts, let alone refuse an opportunity to get one.

The technologies and health project had budgets of 14,000 and 10,000 euros respectively. This means that choices need to be made. While the budget for the health project initially provided for three researchers to be hired, after discussion with Congolese colleagues it was decided to hire five. However, this meant that the daily fees had to be reduced. This decision was justified (by Congolese colleagues) saying it was better to give more junior researchers the chance to participate, gain some experience and some money, rather than give fewer researchers the chance to gain a bit more. While completely legitimate as an argument in the Congolese academic context, it haunted the coordinator with a feeling of shame.

Throughout the project, team members also had to manage expectations and perceptions of workload and work conditions (Marchais et al, 2020: 384). First of all, not all work is equally 'visible', as Marchais et al argue. Emails and elaborate instruction messages via WhatsApp are visible and measurable,

whereas the exhausting and costly labour of logistically preparing a field visit, or following up with interviewees, is less apparent. Next, while the project covered operational costs, including for communication, during the data collection period, this was no longer the case afterwards. Still, researchers had to regularly communicate via WhatsApp, or work on shared Google Drive documents or in the NVivo Collaboration Cloud. While obviously facilitating collective work, this also placed a financial burden on the shoulders of the team members.

My participation in this project has allowed me to present to a large audience what motivates me in doing research on mining. In that sense, the presentation I made at the conference on 12 November was very important to me. It was an excellent showcase for my involvement in the project (one of the contributors to this special issue).

The projects created a space for all researchers to develop their own research ideas, according to their interests and respective expertise. At the same time, it provided a space for exchange around these ideas. After data collection, all interviews were transcribed and imported into NVivo Collaboration Cloud. Coding was a collective process. From there, all author teams went on to develop their own interpretation. The first drafts of the French working papers received feedback from the editors as well as two other team members. Finally, on 12 November 2021, CEGEMI organized a conference in Bukavu to present the research results. It was attended by more than 100 students, researchers, miners and mining cooperative leaders, civil society and government representatives.

Doing research and working in a team is a continuous learning process. What have we learned, so far, from this experience? First of all, despite our efforts to maintain equal and just work relations, power remains in the hands of those who control the financial resources. It is not a bad thing to be continuously reminded about differences in working conditions, as it is possible to change certain practices. Second, exchanging perspectives across disciplinary borders is both an enriching and a humbling experience. All team members have been compelled to challenge ideas they took for granted, and to ask questions they had never thought of before. Despite the fact that the more senior researchers believed they 'knew' the reality in those mines, having done research there before, they discovered many new things. What we present in this special issue is not just an in-depth case study of two mines in the DRC, but an ultra-deep and layered view on these mines (acknowledging that it would have been even more interesting to add a geologist to the team). In addition, we believe that our findings have broader relevance. The transformations they testify to are not at all specific to the DRC. In fact, as indicated by the authors, the DRC is a relative latecomer when it comes to technological innovation in ASGM. Situating these transformations in DRC's specific historical mining trajectory, as we do in section 3, allows us to understand the more structural dimensions. Combined with this structural perspective, the various articles in this special issue paint a rich picture of how different categories of miners experience these transformations.

3. Tracing transformations

The articles in this special issue collectively aim to understand the recent transformations in ASGM in Eastern DRC. These transformations need to be understood in a larger context of 'twinning ASM-LSM trajectories' (Kamundala, 2012; Radley and Geenen, 2021; see also Geenen, 2015 and Radley, 2019). In the early 20th century, the Belgian subsidiary *Société minière des Grands Lacs* (MGL) started gold exploration in what is now South Kivu Province. From the 1930s onwards, new capital and technology investments boosted gold production. Kamituga, with its rich Mobale deposit – an underground mine - developed into South Kivu's major gold mining town of the colonial era.

After Congolese independence in 1960, the industrial mines (gold as well as tin) remained in the hands of MGL. In 1976, MGL merged with a number of other foreign mining subsidiaries into *Société minière*

et industrielle du Kivu (SOMINKI), where twenty-eight per cent of the shares were held by the state and seventy-two by private Belgian capital. By then, however, informal ASGM had already started to spread. Initially consisting of panning and manual digging in remote corners of SOMINKI's concession, by the 1970s it had reached the Mobale mine. Clandestine miners (or Ninja, as they were known and referred to themselves locally) used to mine there at night, protected by SOMINKI's security guards and selling the gold to a rapidly developing above-ground network of traders, extending all the way to neighbouring Uganda and Burundi. ASGM production quickly expanded, making up a quarter to one third of industrial production in the 1970s and 1980s. In Misisi, ASGM started around 1965.

Meanwhile, falling international commodity prices combined with crumbling infrastructure and a broader socio-political crisis brought industrial production across the DRC to a near complete standstill by the early 1990s. In South Kivu, while SOMINKI was already looking for a buyer, the start of the first Congo War in 1996 triggered its definitive departure from Kamituga. During both Congo wars (1996-2002), ASGM came to drive a regional war economy. Incited by soaring commodity prices (including the so-called coltan boom) and driven by people's desire to flee rural insecurity, tens of thousands of people settled in the mines. After 2010, spiking gold prices combined with regulatory efforts targeting tin, tungsten and tantalum (3T) drove thousands of people from 3T into gold (Weyns et al, 2016). Based on data from 2014, Kamundala et al. (2015, 171) estimate South Kivu to produce around 4,800 kilograms of ASM gold annually, which in 2019 equated to a market value of around \$216 million. In 2016, Weyns et al estimated the total annual value at \$437 million. Almost all of this is informal. The number of people involved in mining in Eastern DRC is estimated at 200.000 to 300.000 (Weyns et al, 2016).

Since the end of the wars, transnational mining companies have regained interest in the 3T and gold deposits in the area. The only one that entered into production was Canada-based Banro Corporation, first in Twangiza (in South Kivu) and later in Namoya (in neighbouring Maniema Province). Banro also holds the exploitation permits to the Kamituga concession, but never started production there. In September 2019, the company suspended all operations and its Twangiza mine was taken over by the Chinese investment fund Baiyin, one of its principal shareholders (Radley and Geenen, 2021). Industrial production has never taken place at Misisi, but in recent years the exploration company Casa Mining, registered in the British Virgin Islands, has been active in the area.

In recent years, and as noted at the outset, ASGM in South Kivu has been (and is still) undergoing a process of technologically driven transformation at a scale and speed previously unseen in the province. This has spanned the use of semi-industrial river dredging machines by Chinese firms along the Ulindi river in Shabunda (Global Witness, 2016), to the use of ball mills by Congolese entrepreneurs in Kamituga (Radley and Geenen, 2021). Among the drivers of these recent transformations, the articles in this special issue foreground 1) technological innovation and adaptation, 2) capital investment and 3) socio-political reorganization.

3.1. Technological innovation and adaptation

In all the articles, machines, technologies and techniques figure prominently. Technology in our study refers to the objects and tools that are used in the extraction or processing of minerals: some tools are manual; others are mechanized (machines). Technique on the other hand is the manipulation of these tools by humans (as in different uses, adaptations, tricks), which implies a certain know-how or technical expertise.

In their contribution, Simon Marijsse and Thierry Munga Mwishu argue against the qualification of the current technologies as 'new' technologies. They trace the origins of small air compressors and mobile water pumps with diesel engines back to colonial times. While back then, air compressors were used

to drive pneumatic tools such as drills, nowadays they are used to ventilate underground tunnels. Marijsse and Munga then go on to detail the introduction of motor-driven pumps in the late 1990s. They show the ambivalence of the current widespread use of Chinese diesel pumps across South Kivu. On the one hand, they allow miners to reach deeper underground; on the other hand, they produce toxic, yet invisible and odorless fumes. Using creative adaptations of available components, local engineers seek to fight against these mortal fumes. Through detailed ethnographic description and with visual contributions from Robert Carrubba's photographic work, the authors foreground local narratives and agency surrounding the socio-technical modifications and adaptations.

This focus on adaptation, agency, and technical knowhow is something all articles have in common. In their article on productivity and profitability, Divin-Luc Bikubanya and Ben Radley highlight how ball mill technology has been adapted and remodeled to suit the local context in Kamituga. Similarly, in their article on labour regimes, Phillipe Dunia Kabunga and Sara Geenen pay attention to the skills and expertise of different categories of miners, and how certain skills have come to be in high demand, having a positive effect on their earnings. In their contribution on responsible technologies, Nkuba et al show that miners use specific techniques that aim to reduce the impact of their activity on their health. In this article, we also learn about the marked distinction between visible or 'smellable' harms, such as acid fumes or dust, and invisible harms such as mercury. Some workers try to protect themselves from the former, while very few have knowledge about the latter. This bears some parallel with the work of Marijsse and Munga, although the toxic fumes they write about are not perceivable at the moment itself, yet they become all too quickly apparent when underground workers start to faint and, in the most severe instances, die. These toxic fumes directly kill, while the environmental and health impacts of mercury take longer to manifest.

3.2. Capital investment

The introduction of new technologies and mechanization in South Kivu's ASGM sector requires more capital investment. Radley (2021) has documented how this investment can come from local Congolese shaft managers (or PDGs) and gold traders, drawing either on profits accrued from ASGM or on family wealth, often held in livestock, especially cattle. Investment can also, however, come from foreigners. Dunia Kabunga and Geenen note that in Misisi, Tanzanians have created waste processing units, and that a cyanide processing plant in Kamituga is funded by a large economic operator in Bukavu with a Tanzanian presence among its staff.

Looking at how technological transformation has altered financing arrangements, Dunia Kabunga and Geenen observe new dynamics in the underground pits of Kamituga leading to a concentration of capital. They note that where previously, the construction of these pits was financed by the PDG himself, or by gold traders through prefinancing arrangements, more recently, ball mill owners have taken over this role. While some of these ball mill owners are former PDGs, others are key players in local miners' cooperatives or simply local businessmen seeking investment opportunities.

Bikubanya and Radley calculate that an investment of between \$4,000 to \$7,000 is required to own a fully functioning ball mill, and that some ball mill owners in Kamituga own anywhere from several up to a dozen. Further underscoring the notion of technological transformation leading to capital concentration, Bikubanya and Radley highlight how, due to the high profitability of ball mill operations, once a single ball mill has been acquired, the owner can continue to accumulate more ball mills without further recourse to external capital, but simply by reinvesting the profits from the activity itself.

3.3. Socio-political reorganization

The process of formalizing ASGM in DRC received a first push in 2011, after a six month mining ban had suspended all ASGM in the Eastern provinces (Geenen, 2012). When the ban, which had a

devastating impact on livelihoods, was finally lifted, miners were ordered to group into cooperatives. Since the introduction of the 2002 Mining Code, ASGM is only possible in legally established artisanal mining zones. Mining cooperatives can apply for permits to work in these mining zones. In practice, many cooperatives are working – with or without the official permit – outside artisanal mining zones. This is the case in Kamituga, which is legally still in Banro’s concession, but where seven cooperatives are active. In Misisi, two artisanal mining zones were created in 2016 and three cooperatives are currently active in these zones.

The mechanization of gold production seems to have significantly reinforced the position of miners’ cooperatives. Dunia Kabunga and Geenen document two main effects. First, cooperative leaders invest in the acquisition of machines such as ball mills, and also gain control of other nodes in the production process, such as the *domaines* where tailings are processed. Financial capital becomes more concentrated in the hands of a few financiers, which in turn further reinforces their power position. Second, the spatial reorganization of the sites around the ball mills and the *domaines* allows for a more centralized control of the entire production process. While this has some advantages – Dunia Kabunga and Geenen mention it allows for the production to be more secret, with positive effects on miners’ personal security – it also gives more power to the cooperatives, which are overseeing the whole production process.

At different points in time, the Congolese government has expressed the ambition to develop the artisanal mining sector into small-scale, semi-industrial mining (Ministry of Mines, 2010, 2017a, 2017b). So far policy has done little to push that agenda. Most of the country’s mineral deposits have been assigned to large scale exploration or mining companies, leaving little space for legal small-scale mining. However, this has not stopped small-scale mining operators from expanding their own operations, as is testified in the cases of Kamituga and Misisi that take center stage in this special issue. All over South Kivu, small-scale operators are extracting gold on a larger scale than before, having equivalent social and environmental consequences (see section 4). In Shabunda territory, for instance, mechanical and automated dredges are now sucking vast quantities of sand from the riverbeds. In Mwenga territory, Chinese private investors use excavators and dredges to produce large amounts of gold. They do so by making illegal partnerships with registered cooperatives. After multiple protests by the local population, including complaints about polluted water and destroyed crops, these companies were ordered by the Congolese government to suspend their operations in 2021 (Sabbe, 2021). In other words, small-scale gold mining operators are ‘economically upgrading’ their activities (Radley and Geenen, 2021), yet they do so – for a considerable part – outside of the legal framework.

4. Transforming humans and nature

This special issue also addresses the impact on human health, on human labour, and on nature. In their contribution Nkuba et al. demonstrate that the local health system is not able to protect miners and their families from the harmful impacts of new technologies. Due to lack of health insurance or any form of mutualization of health cost, miners and local residents have to rely on traditional healers, self-medication, or pharmacists selling drugs without running appropriate medical checks. People often go to the hospital when it is too late. In addition, hospitals are under-equipped and their staff under-trained, certainly when it comes to medical problems that are specifically related to mine work.

A specific focus on women’s health is provided in Geenen et al. The health risks women face are related to their reproductive roles, but also to the specific tasks they carry out in mineral production. In the sites under study, women are mostly involved in reprocessing the tailings and picking or transporting stones. These tasks not only involve physically demanding manual labour but also expose them to different risks related to the polluted waters in which they work. In their contribution, Geenen et al. study issues such as hygiene, sexual health, prenatal and postnatal care, nutrition, gender-based

violence, and physical and psycho-social trauma. Based on extensive interviews with female mine workers, the authors trace some pathways towards a better protection of women in the mines.

Another effect of technological transformations can be observed through labour. Indeed, as analysed by Dunia Kabunga and Geenen, work organisation and required skills have significantly changed. The article details how the introduction of metal detectors, ball mills, gravity concentration platforms, cyanidation plants, jackhammers, excavators, and bikes give rise to a wide range of 'new' worker categories and a valorization of particular skills, while other categories of worker are disappearing. Another change is taking place at the level of distribution. While in the past, artisanal production was characterised by output sharing agreements, there is now a move towards wage work. Investments in new technologies require higher capital investment, resulting in more capital concentration and a shift of power to the holders of capital. Finally, cooperatives have increased their control over production.

The impact on nature, finally, is also discussed in Nkuba et al. Their contribution highlights the environmental impact at different nodes in the value chain. The authors analyse the negative impacts, while recognizing the positive impact mining technologies have on miners' productivity. For this reason, they qualify technologies such as mercury, cyanidation, and ball mills as a 'necessary evil'. At the extraction node, researchers as well as local residents have witnessed impacts on deforestation and biodiversity, on soil degradation and erosion while the use of explosives, evacuation of water and oxygen injection in pits create health risks causing many injuries and deaths. In the processing phase, air and river pollution by crushed ore as well as mercury and cyanide pollution of local rivers are very common, with little to no effort being made to prevent or mitigate them.

5. Conclusion

Taken together, the articles in this special issue point to several sources of tension and contradiction within processes of ASGM technological transformation in South Kivu. Bikubanya and Radley point to the increased productivity and profitability of ASGM in Kamituga, both important developments in a sector previously characterised for its low levels of both. As detailed by Dunia Kabunga and Geenen, technological change in ASGM impacts different groups of workers in different ways, with certain categories of labour stifled while others are strengthened. This differential impact is also gendered, as evidenced by Geenen et al, who demonstrate how the introduction of mechanized ball mills pushed a certain group of female ore crushers out of work, while opening up opportunities for new female-dominated forms of employment. Moreover, as Marijsse and Munga point out, the introduction of ASGM technologies recalls for many miners past colonial harm and injustices, while also posing new threats to their health and, in the most extreme circumstances, survival. This point is further elaborated by Nkuba et al, who detail not only the ways in which technological change negatively impacts on the health of workers, but also on their surrounding environment.

Yet, and perhaps above all, the articles highlight how neither the adopters of technologies, nor the workers impacted by their adoption, are passive actors beholden to structural forces beyond their control. On the contrary, they are constantly innovating and adapting in response to the evolving circumstances they find themselves in. Nkuba et al detail how, faced with often distant formal health structures, miners have developed their own strategies of self-medication that enable them to respond to suffocation and other emergency health issues as they arise on-site. Both Bikubanya and Radley and Marijsse and Munga draw attention to the technological knowhow and depth of ingenuity deployed by miners as they seek to adapt, repurpose, and make anew a range of technologies to better suit and respond to their localised needs. Dunia Kabunga and Geenen document forms of 'solidarity financing' among female waste processors who – in response to *domaine* owners' refusal to sell their tailings in small quantities – collectively pool their capital in order to gain access to them. Women's agency is again in evidence elsewhere in this special issue, as Geenen et al. place a strong focus on the various

and remarkable ways in which women work and provide for family needs under the most difficult of circumstances, at times challenging socio-cultural norms in the process. While certain aspects of these sources of tension and contradiction are specific to the context of South Kivu, we can theorise that similar dynamics – such as the reorganization of labour, or the creation of new threats to health and the environment – are likely to be reproduced in other ASGM regions undergoing similar transformations. As such, the trends observed by the articles in this special issue call for further research into how technological transformations in ASGM are shaping and being shaped by the economic, political, social, cultural, and environmental contexts within which they are embedded.

The collective research effort on which this special issue is based, similarly brings out points of tension and contradiction which are part of the learning process. We acknowledge that our collaborations are rife with power inequalities, whereby power is ultimately balanced in favour of those controlling the financial resources. But spaces can be created where the dignity and contribution of all researchers is valued, and where material working conditions are improved. These spaces, we argue, can (more easily) grow in the context of long-term institutional partnerships where individual commitment (of senior researchers) and financial sustainability (not depending on only one short-lived source of funding) are important conditions.

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