HOW (UN)SAFE IS ASM? COUNTING AND CONTEXTUALIZING FATALITY FREQUENCY RATES

AUTHORS: James McQuilken and Dylan McFarlane
ORGANIZATION(S): Pact

INTRODUCTION

In February 2020, one of America's largest newspapers, the Wall Street Journal (WSJ), ran the article "Many Miners Die, and It Never Shows Up in Safety Data" (Macdonald and Pokharel 2020). Citing the Delve 2019 ASM employment figure of 40 million people (World Bank, 2019), the exposé highlighted the "widely acknowledged" issue of underreporting of accidents in ASM (ILO 1999a, p13). The authors report that in India the official death toll from mining in 2018 was 120 people but could reach as many as 20,000, and in DRC unofficial figures suggest up to 2,000 artisanal and small-scale miners die each year. But while these numbers are stark and highlight the challenges of reliable data and reporting, the scale and drivers of the health and safety issues in ASM remain unclear. As rightly pointed to in the WSJ article, the "lack of data" and underreporting of incidents "distorts mining's safety record and makes it harder to detect and improve potential hazards" (Macdonald and Pokharel 2020, 1).

The greater public attention and high-profile campaigns from the likes of Human Rights Watch (2015) and Amnesty International (2016) could also be distorting the picture. Exaggerated reporting focused mainly on the negative impacts of ASM gives the impression that the sector has a worse health and safety record than perhaps it does. These reports combined with availability and negativity biases—whereby a person's perception of an event is judged on how easily memories of similar instances come to mind and for negative events to be retained more readily than positive ones—can compound the narrative further. Meanwhile, without comparison to other industries or an examination of the evolution of health and safety in mature mining economies, such as Australia, South Africa, and the USA, it is difficult to make a robust and fair assessment of the labor conditions endured by small-scale miners. Indeed, the labor-intensive mining methods, risks, and fatality rates over the last century in those countries are the same as those observed in developing countries like Colombia, Ghana, and Indonesia today.

To better assess how (un)safe ASM conditions are, the first step is to collect data according to SDG8 Indicator 8.8.1—the frequency rates of fatal and non-fatal mining injuries. A second step is to then contextualize and benchmark this information against other occupations and industries as well as large-scale mining operations, which are more heavily regulated and for which better data exists.

Counting fatalities in ASM

One source of data is from the ILO's seminal report "Social and labour issues in small-scale mines" (ILO 1999a) (see appendix Table 11). The report includes a section dedicated to OSH as well as the results of a survey that asked government agencies, chambers of mines, and trade unions across Africa, Asia, and Latin America to estimate the number of fatalities attributable to ASM in their countries each year. Used to inform discussions at a meeting between governments, employers, and workers on ASM held by the ILO in Geneva in the same year, the report was instrumental in placing health and safety squarely on the agenda. Participants of the meeting "unanimously adopted" 34 conclusions. One of which made clear the need for better data on the issue:

> **'8. Occupational safety and health (OSH) are important issues for small-scale mines and their communities. The lack of reliable data and difficulties in its collection makes it more difficult to develop effective assistance programmes and to improve safety and health performance.'**
> (ILO 1999b, 21)

Yet despite this recognition and the call made 20 years ago for governments to "establish a regime for effective reporting on safety and health performance in small-scale mining" (ILO 1999b, p.22), to date, no comprehensive databases that compile statistics from multiple data sources on fatalities in ASM exist.

To begin to address this data gap, a useful start point is a data set compiled by McFarlane (2020) for this report. Using a combination of relevant search terms in Google, an Excel pivot table disaggregated by nine categories including date, country, cause, and mineral being extracted was populated.[1] The initial results, though limited, are powerful.

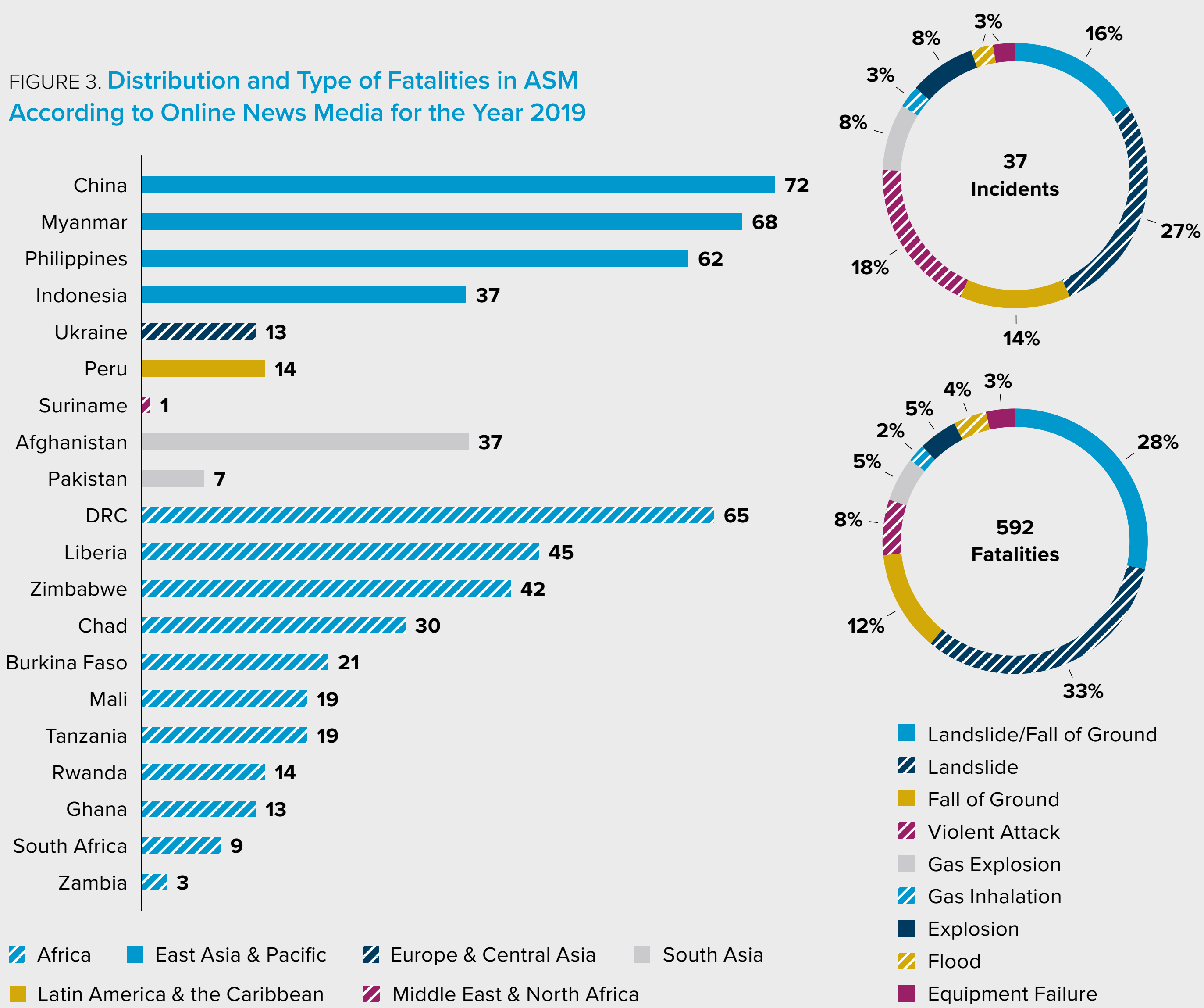
The data show that for the year 2019 there were 592 ASM fatalities in 37 separate incidents across 20 countries reported in online English language news media (Figure 3). The deadliest, and most common fatal ASM accident, is from landslides and falls of ground which combined account for 73 percent of fatalities and 57 percent of incidents. After this, gas explosion, gas inhalation, and explosion accounted for 73 fatalities resulting from 9 incidents. Of these, approximately three quarters were attributed to coal mining in Afghanistan, China, Pakistan, and Ukraine. This corresponds with the ILO's observation that "the three countries with the highest number of underground coalmines (China, India, Pakistan) have significantly higher numbers of fatal accidents" (ILO 1999a, 13). Underground coal mining has always been the most hazardous type of ASM, and even in developed nations there are history of coal mining disasters, such as Courrieres in France in 1906 (1,099 fatalities), Senghenydd in the United Kingdom in 1913 (439 fatalities), and

Coalbrook in South Africa in 1960 (435 fatalities) (Mining Technology 2014). These miners were using similar techniques as modern ASM use today.

The data reinforces the need to have a nuanced approach to addressing specific health and safety issues depending on the type of ASM activity. For example, coal mining, regardless of scale, carries the risk of explosions caused by fine dust particles being ignited by heat sources as well as risks due to inhalation of carbon dioxide, carbon monoxide, methane, and other hydrocarbons. Mining for alluvial gold and construction minerals carries a greater risk of flooding and landslide due to the unstable soil and opencast extraction methods in often water-logged soils. However, the greatest overarching risk factor was underground mining which accounted for 35 of the 37 fatal incidents in 2019. For gold mining, this included 13 fatalities in Ghana when blasting by a large-scale operator created a smoke cloud that killed nearby small-scale miners working underground (Hazardex 2019) and 8 fatalities in Zimbabwe when small-scale miners that had encroached into the tunnels of a large-scale concession were killed by explosions set off by another ASM group (Casey 2019). These events also show the operational safety risks when large- and small-scale mining operators unexpectedly meet.

Despite the limitations of this data mining exercise, it shows the types of inferences that can be made when data sets on the sector are compiled. If this

FIGURE 3. **Distribution and Type of Fatalities in ASM According to Online News Media for the Year 2019**



Source: Graph and table extracted using McFarlane (2020) data set on ASM fatalities.

process could be automated and combined with artificial intelligence applications, including "text data mining" by extracting new information from multiple written sources and in different languages, powerful insights could drive better targeted ASM interventions. This would substantially reduce the manual labor to compile such a database while also improving its accuracy by ensuring the dataset is more complete. In turn, such an automated database could be made a public good through platforms such as Delve. It could then be possible to establish disaggregated frequency rates of fatalities and injuries in ASM (SDG indicator 8.8.1) and make significant discoveries to guide policymakers and practitioners to develop more appropriate and targeted initiatives to improve safety.

Contextualizing fatality rates in ASM

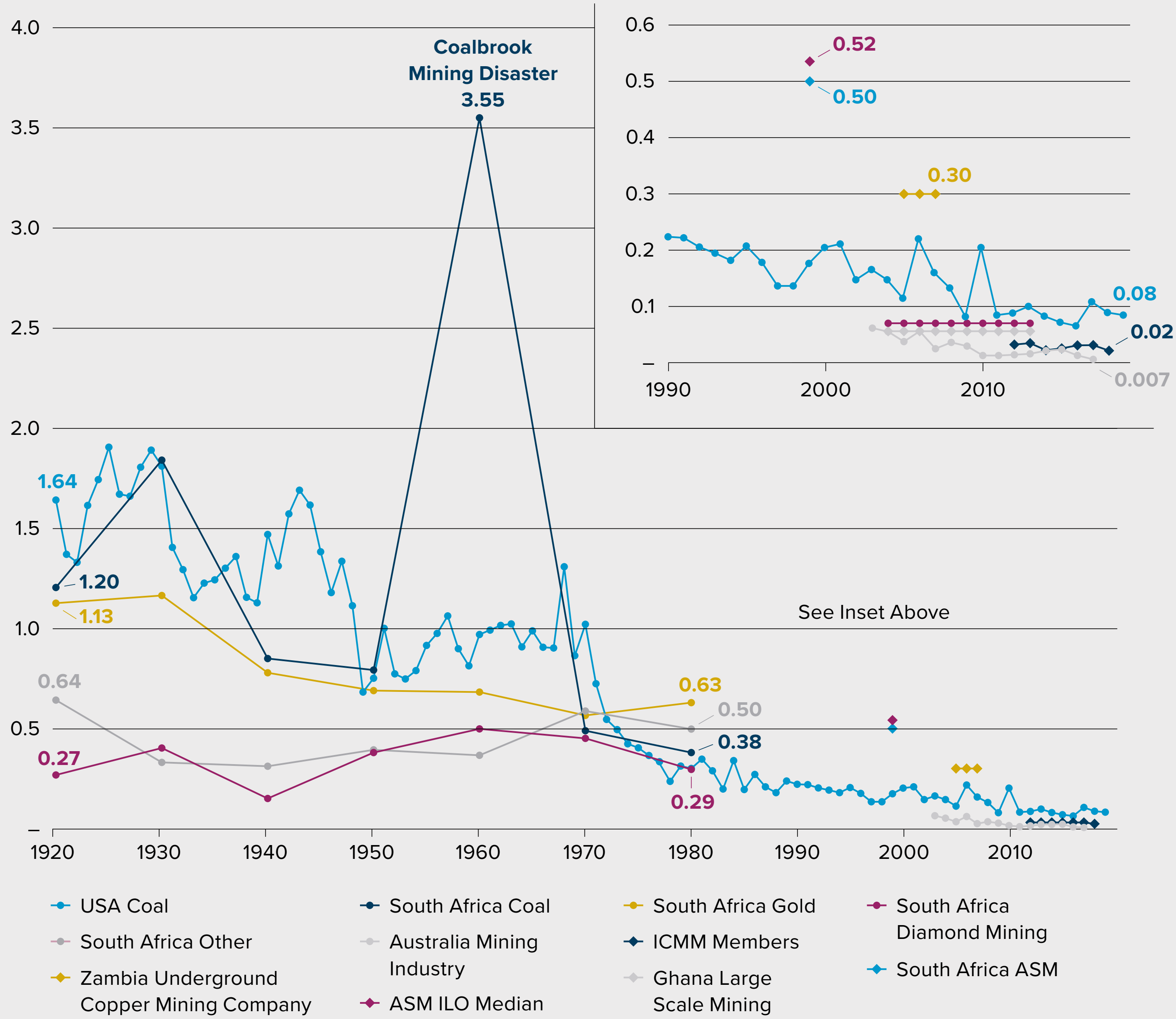
A key source of information that can be used to contextualize the health and safety record of the ASM sector is the fatality frequency rate (FFR).[2] This is defined as the number of fatalities per 1 million hours worked. Using the high and lower limits of the annual fatality data and employment estimates derived by the ILO (1999a) from their questionnaires for 23 countries and an assumption of 1,650 hours worked per miner per year, an approximate FFR for ASM in 1999 is calculated to be 0.47-0.64 (see the appendix, Table 11). The model assumptions on average annual number of hours worked are based on a range of project and published data regarding seasonality and rural livelihood patterns (ILO 1999a; Pact 2015; Dreschler 2001; Hentschel, Hruschka, and Priester 2002; Mwaipopo 2004; Kühn 2017; Barreto et al 2018; Republic of Sierra Leone 2018; Chupezi, Ingram, and Schure 2009).

Another method to estimate, and as per the Delve "best practices for reporting ASM data" (World Bank 2019, 71), triangulate the FFR for the ASM sector is based on the assertion that small-scale mining has "a workplace fatality rate up to 90 times higher than mines in industrialized countries" (ILO 1999c). Meaning that depending on how this quote from the ILO's press release accompanying the report is interpreted, an FFR for ASM can be crudely estimated based on it being 90 times greater than the FFR for large-scale mining (LSM). A recent data set published by the International Council on Mining & Metals (ICMM 2019, 5), which represents 27 of the world's largest mining companies and accounts for most of the world's large-scale mining workforce, offers a useful measure for the LSM sector.

For the years 2012-2019, the mean FFR for ICMM member companies was 0.04 based on 748 "recordable fatalities" and over 18 billion work hours—this includes the catastrophic failure of a tailings storage facility at Vale's Corrego do Feijão mine in Brumadinho, Brazil, which killed at least 248 people (ICMM 2019, 1). Using ILO's assertion that ASM is up to 90 times more fatal than LSM, this produces an FFR for ASM of 3.62 which is impossibly high. In context, this would equate to 250,000 fatalities in ASM every year and for an artisanal miner who spends 40 years mining and works 2,000 hours full time per year, it would represent a one in three chance of a fatal accident.

A second measure for the FFR of large-scale mining is to use a mean calculated from a range of available sources for Ghana (Stemn 2019), South Africa (Leger 1991; Hermanus 2007), Ukraine (ILO 2018), USA (USDOL 2020a; 2020b), and Zambia (Michelo, Bråtveit, and Moen 2009) (Figure 4). The average is 0.516 and produces an even higher FFR for ASM of 47, which when extrapolated would imply 3.3 million ASM deaths per year. While ASM is certainly more hazardous than LSM, the idea that it is "90 times more deadly" is therefore inaccurate. Using the Google search exercise and ILO data as benchmarks, an FFR for ASM of approximately 0.5 is much more likely. As the graph shows (Figure 4), this also correlates with the FFR for LSM in Australia, the USA, and South Africa for much of the 20th century (Figure 4), as well as the current FFRs for poorer countries such as Brazil (0.83) and Zambia (0.13) that can be calculated from the ICMM data (ICMM 2019). Further triangulation is also possible using the best approximate FFR of 0.5 and the Delve 2020 global employment estimate, which suggests approximately 30,250 fatalities in ASM per year (Table 1). A sobering, but not unlikely number.

FIGURE 4. **Comparing the Fatality Frequency Rate of ASM versus LSM (1900-2019)**



Sources: Hermanus 2007; ICMM 2019; ILO 2018; Leger 1991; Michelo, Bratveit and Moen 2009; USDOL 2020a

Notes: Different number of hours worked per miner per year have been used to calculate the FAR from reported fatality rates: USA coal = 1,768; South Africa = 2,209; Australia = 2,000; South Africa ASM, ILO ASM = 1,650; Mutoshi Cobalt Pilot Project = recorded number of hours.

TABLE 1. **Number of Fatalities in ASM Per Year Based on Fatality Frequency Rate of 0.52**

Global ASM employment in 2020	42,000,000
Part-time employed total hours (1,000 hours per miner per year)	14,500,000,000 (65% of global employment)
Full-time employed (2,000 hours per miner per year)	56,000,000,000 (35% of global employment)
Total ASM hours per year	70,500,000,000
Estimated ASM fatalities per year using FFR of 0.52	**30,250**

Source: Delve (2020)

COMPARING FATALITY RATES IN ASM TO LARGE-SCALE MINING

On their own, however, these FFRs mean little, and extrapolating in this way from such limited data is risky. But when compared with estimates for industrial mining and other sectors, it is possible to derive some initial insights and demonstrate what could be possible if better data on fatalities in ASM was collected.

A first useful comparison is against USA coal mining for which there is a rich data set stretching back to 1900 (USDOL 2020a). Figure 4 illustrates a declining FFR of industrial coal mining in the USA over the last century with a peak in 1907 of 2.69 to a low of 0.08 in 2019. It was not until 1972—with over 60 years of safety improvements—that the FFR for USA coal mining dropped to the same level that ASM was operating at in 1999. For a sector that has received limited support to improve health and safety, it is remarkable to consider that ASM lags just 30 years behind the large-scale mining industry of the USA. While the FFR reduction for the USA's coal mining industry is likely due to increased mechanization (Table 2), it is also noteworthy to consider what impact the significant investment spearheaded by the establishment of the US Department of Labor's Mine Safety & Health Administration (MSHA) in 1977 has also had. Today, the MSHA runs a sophisticated program including online quarterly training calls and has an annual budget in excess of US$376 million (MSHA 2019)—a figure that would undoubtedly yield significant improvements in safety if also invested into ASM each year.

TABLE 2. **USA Large-Scale Mining Coal Production and Employment Data 1985-2015**

Year	Total employment	Number of coal mines	Total production (million short tons)
1985	169,300	3,355	878,500,000
2000	71,500	1,513	1,073,900,000
2015	65,900	834	896,900,000

Source: CRS (2017)

A second comparison is against the similar trends in declining mining industry FFRs can be seen in South Africa. Here, for gold, diamond, coal, and 'other' types of mining, the FFR had declined to the same level as estimates for ASM in 1980. Not only do these comparisons help contextualize that ASM, while it remains a hazardous occupation, is no different from the risks and poor labor conditions suffered by miners in developed countries in recent history; but it also demonstrates there is a pathway for improvement. This is especially true given that many of the more labor-intensive mining methods used in large-scale mining 30 years ago are exactly the same as those used at artisanal and small-scale mine sites today.[3] With even a fraction of the level of funding, high-level support, and dedicated programing the large-scale mining sector has received to address health and safety, there is no reason why the ASM sector could not also substantially improve its safety record.

The case studies accompanying this section of the report demonstrate this well. At the Mutoshi Cobalt Pilot Project in Kolwezi, DRC since the start of Pact and Trafigura's interventions to improve mine safety in February 2018 until the temporary suspension of activities on site in March 2020, Shumsky (2020) reports that no fatalities among participating artisanal miners have been recorded. Meanwhile, as explained by Limpitlaw and McQuilken (2020), the Sustainable Development of Mining in Rwanda program has been piloting a novel way to enhance safety through simple and cost-effective measures that can also increase profits thereby incentivizing ASM companies to make changes.

TABLE 3. **Fatality Frequency Rates for Other Industries and Activities Per Million Hours Exposure**

ASM	
ILO 1999 data set range	0.47-0.64
ILO 1999 data set average	0.52
USA (2018)[1]	
Fishers	0.50
Logging workers	0.42
Aircraft pilots & flight engineers	0.24
Roofers	0.23
Activities (1973)[2]	
Travelling by car	0.57
Travelling by bicycle	0.96
Travelling by air	2.4
Rock climbing	40
Canoeing	10

Source: 1 - U.S Bureau of Labor Statistics (2018); 2 - Bulloch (1973); Gibson (1973)

A final benchmarking and reappraisal of the ASM safety narrative is to compare to fatality rates in other occupations, industries, and activities. To put it into perspective, the FFR of ASM is comparable to the fishing and logging industry in the USA and less risky than travelling by bicycle or air was 30 years ago (Table 3).

Conclusion

There are significant methodological limitations of the FFR calculations for ASM presented here, most notably due to limited data. Comparisons against coal mining, which as outlined has much higher risks than other minerals, also skew the relative risk of ASM, as does the inclusion or exclusion of disasters. This analysis is, however, the first systematic attempt at modelling FFR in ASM. The initial findings suggest that while unreasonably high, the rates of fatal incidents in ASM might not be as staggering as some narratives about the sector suggest. From the available data, a FFR for ASM of 0.47-0.64 was calculated, which is ten times higher than LSM, although it is comparable to LSM rates in the 1960s as well as with many modern occupations like fishing and logging in the USA today. Changing the narrative and demonstrating that, like LSM, with sufficient attention and investment improvements to safety can be made, and it will also help unlock more support for formalizing ASM. With better data, the modelling could be improved further. This will promote evidence-based policy making, more targeted and sustained interventions, and improve health and safety of the sector as well as track progress against SDG8.

ACKNOWLEDGMENTS

This overview is posthumously published by and dedicated to Dylan McFarlane who was a passionate and dedicated champion of improving OHS in ASM. His leadership, enthusiasm, and expertise applied to Delve since its inception were critical in turning the platform into a reality.

END NOTES

1 This search and analysis were performed by Dylan McFarlane of Pact and the results were collated into an Excel pivot table. Where specified in the news article, the data were disaggregated to note the date, country, number of fatalities, mining method (underground/ open pit/ unspecified), mineral, cause, notes, and internet link to the source. The search terms were in English only and used variations and combinations of the following terms: ASM, artisanal, small-scale, mining, death, fatality, disaster etc.

2 Also referred to commonly as the Frequency Accident Rate (FAR). However, the term FFR is used here to recognise that through improved measures such fatal incidents can be prevented and thus are not accidental.

3 For example, deep South African gold mining by the likes of Anglogold Ashanti, Goldfields, and Randgold use the same equipment and techniques as neighboring ASM in Zimbabwe for similar underground deposits.

REFERENCES

Amnesty International. 2016. This is what we die for. *Human rights abuses in the Democratic Republic of the Congo power the global trade in cobalt*. https://www.amnesty.org/download/Documents/AFR6231832016ENGLISH.PDF

Barreto, ML, Schein, P, Hinton, J & Hruschka, F. 2018. *Economic contributions of artisanal and small-scale mining in Kenya: Gold and gemstones*. East Africa Research Fund, Department for International Development

BBC. 2019. *Myanmar landslide buries at least 54 jade miners*. BBC News. https://www.bbc.co.uk/news/world-asia-48028971

Bnamericas. 2017. *Brief: Artisanal miners die in Nicaragua accident*. Bnamericas. https://www.bnamericas.com/en/news/brief-artisanal-miners-die-in-nicaragua-accident

Bose-O'Reilly, S., Lettmeier, B., Gothe, R., Beinhoff, C., Siebert, U., and Drasch, G. 2008. "Mercury as a serious health hazard for children in gold mining areas." *Journal of Environmental Research* 107(1):89-97. 10.1016/j.envres.2008.01.009

Bulloch, B.C. 1973. *The development and application of quantitative risk criteria for chemical processes*. Quantitative Measurement of Process Safety, Institute for Chemical

Engineering Symposium Series No. 49.

Casey, J.P. 2019. *Gold mine explosion kills eight and injures two miners in Zimbabwe*. Mining Technology. https://www.mining-technology.com/mining-safety/gold-mine-explosion-kills-eight-and-injures-two-artisanal-miners-in-zimbabwe

Chupezi, T.J., Ingram, V., and Schure, S. 2009. *Impacts of artisanal gold and diamond mining on livelihoods and the environment in the Sangha Tri-National Park landscape*. Center for International Forestry Research: Indonesia.

CRS (Congressional Research Service). 2017. *The U.S. Coal Industry: Historical Trends and Recent Developments*. Congressional Research Service USA: https://www.everycrsreport.com/reports/R44922.html#_Ref490124296

Delve. 2020. Delve. World Bank and Pact. https://delvedatabase.org/

Dreschler, B. 2001. *Small-scale Mining and Sustainable Development within the SADC Region*. Minerals Mining and Sustainable Development. International Institute of Environment and Development.

GEF (Global Environment Facility). 2020. *Global Opportunities for Long-term Development of ASGM Sector*. GEF GOLD. https://www.thegef.org/project/global-opportunities-long-term-development-asgm-sector-gef-gold

Gibson, S.B. 1973. *Quantitative Measurement of Process Safety*, Institute for Chemical Engineering Symposium Series No. 49.

Hazardex. 2019. *Thirteen miners killed at Chinese-owned gold mine in Ghana*. http://www.hazardexonthenet.net/article/165100/Thirteen-miners-killed-at-Chinese-owned-gold-mine-in-Ghana.aspx

Hentschel, T., Hruschka, F., and Priester, M., 2002. *Global Report on Artisanal & Small-Scale Mining. Minerals, Mining and Sustainable Development*. International Institute of Environment and Development.

Hermanus. 2007. "Occupational health and safety in mining—status, new developments, and concerns." *The Southern African Institute of Mining and Metallurgy*, Volume 107

Hilson, G., and McQuilken, J., 2014. "Four decades of support for artisanal and small-scale mining in sub-Saharan Africa: A critical review." *The Extractive Industries and Society* 1(1). 104-118.

Hilson, G., Zolnikov, T.R., Ortiz, D.R., and Kumah, C., 2018. "Formalizing artisanal gold mining under the Minamata convention: Previewing the challenge in Sub-Saharan Africa." *Environmental Science & Policy* 85, 121-131.

Human Rights Watch. 2015. Precious Metal, Cheap Labor. Child Labor and Corporate Responsibility in Ghana's Artisanal Gold Mines. https://www.hrw.org/report/2015/06/10/precious-metal-cheap-labor/child-labor-and-corporate-responsibility-ghanas

ICMM (International Council on Mining and Metals). 2019. *Safety Data. Benchmarking progress of ICCM members in 2019*. International Council on Mining and Metals: London.

ILO (International Labour Organization). 1999a. *Report for discussion at the Tripartite Meeting on Social and Labour Issues in Small-scale Mines*. Geneva: ILO. https://www.ilo.org/wcmsp5/groups/public/---ed_dialogue/---sector/documents/meetingdocument/wcms_714371.pdf

ILO (International Labour Organization). 1999b. *Social and Labour Issues in Small-scale Mines. Report for Discussion at the Tripartite Meeting on Social and Labour Issues in Small-scale Mines*. International Labour Organization, Geneva: Sectorial Activities Programme, International Labour Organization. https://www.ilo.org/sector/Resources/publications/WCMS_677992/lang--en/index.htm

ILO (International Labour Organization). 1999c. *Small-scale mining on the increase in developing countries*. Press Release. International Labour Organization, Geneva. 17 May 1999. https://www.ilo.org/global/about-the-ilo/newsroom/news/WCMS_007929/lang--en/index.htm

ILO (International Labour Organization). 2018. *Occupational safety and health in the mining industry in Ukraine*. International Labour Organization. https://www.ilo.org/budapest/what-we-do/publications/WCMS_670764/lang--en/index.htm

Kühn, E., 2017. *Mining for the Future: Dynamics of Artisanal Gold Mining Practice and Governance in the Balan-Bakama (Mande, Mali)*. A thesis submitted in conformity with the requirements for the degree of Doctor of Philosophy. Graduate Department of Anthropology. University of Toronto.

Leger, J.P. 1991. "Trends and causes of fatalities in South African mines" *Safety Science*, Volume 14, 169-185. https://doi.org/10.1016/0925-7535(91)90019-I

Limpitlaw, D., and McQuilken, J. 2020. *Using a Market-Driven Approach to Improve Economic Returns and Mine Safety* In (eds.) World Bank 2020 State of the Artisanal and Small-Scale Mining Sector Report. Washington, D.C.: World Bank.

Macdonald, A., and Pokharel, K. 2020. *Many Miners Die, and It Never Shows Up in Safety Data*. Wall Street Journal. https://www.wsj.com/articles/many-miners-die-and-it-never-shows-up-in-safety-data-11582815186

McFarlane, D. 2020. *ASM Mining Disasters and Fatalities Data*. unpublished.

Michelo, P., Bråtveit, M., and Moen, B. 2009. "Occupational injuries and fatalities in copper mining in Zambia." *Occupational Medicine* Volume 59, 191-194

Mining Technology. 2014. *The world's worst coal mining disasters*. https://www.mining-technology.com/features/feature-world-worst-coal-mining-disasters-china/

MSFA (Mine Safety And Health Administration). 2019. FY 2020 Congressional Budget Justification Mine Safety and Health Administration. US Department of Labor. https://www.dol.gov/sites/dolgov/files/general/budget/2020/CBJ-2020-V2-13.pdf

Mwaipopo, R., Mutagwaba, W., Nyange, D., and Fisher, E., 2004. *Increasing the contribution of artisanal and small-sale mining to poverty reduction in Tanzania. Based on Analysis of mining livelihoods in Misungwi and Geita Districts, Mwanza Region*. UK Department for International Development.

Pact. 2015. *A Golden Opportunity: Scoping Study of Artisanal and Small Scale Gold Mining in Zimbabwe*. The Chamber of Mines Zimbabwe and Pact. https://www.pactworld.org/library/golden-opportunity-artisanal-and-small-scale-gold-mining-zimbabwe

Republic of Sierra Leone. 2018. *Artisanal Mining Policy for Sierra Leone*. Republic of Sierra Leone.

Shumsky, S. 2020. *Mutoshi Cobalt Pilot Project, DRC: Transforming ASM for increased productivity, safer working conditions, and fairer female earnings* In (eds.) World Bank 2020 State of the Artisanal and Small-Scale Mining Sector Report. Washington, D.C.: World Bank.

Stemn, E. 2019. "Analysis of Injuries in the Ghanaian Mining Industry and Priority Areas for Research." *Safety and Health at Work Journal* 10, 151-165

U.S. Bureau of Labor Statistics. 2018. *National Census of Fatal Occupational Injuries in 2017*. News Release, Tuesday 18th December 2018, Washington D.C., US DOL Bureau of Labor Statistics

USDOL (US Department of Labor). 2020a. *Coal Fatalities for 1900 Through 2019*. Mine Safety and Health Administration (MSHA). https://arlweb.msha.gov/stats/centurystats/coalstats.as

USDOL (US Department of Labor). 2020b. Metal/Nonmetal Fatalities for 1900 through 2019. Mine Safety and Health Administration (MSHA). https://arlweb.msha.gov/stats/centurystats/mnmstats.asp

Veiga, M., and Fadina, O., 2020. "A review of the failed attempts to curb mercury use at artisanal gold mines and a proposed solution." *The Extractive Industries and Society*, 7, 1135-1146.

WHO (World Health Organization). 2019. Artisanal and small-scale gold mining and health. Technical Paper #1: Environmental and Occupational Health Hazards Associated with Artisanal and Small-Scale Gold Mining. WHO.

World Bank. 2019. 2019 *State of the Artisanal and Small-Scale Mining Sector*. Washington, D.C: World Bank. https://delvedatabase.org/resources/state-of-the-artisanal-and-small-scale-mining-sector

APPENDIX

Fatality frequency rate model

The model was designed and calculated by Dylan McFarlane. It is based on reported data on fatalities published in the ILO report "Social and labour issues in small-scale mines" (ILO 1999). The report includes a section dedicated to occupational health and safety (OHS) as well as the results of a survey that asked government agencies, chambers of mines, and trade unions across Africa, Asia, and Latin America to estimate the number of fatalities attributable to ASM in their countries each year. The survey results are reproduced in the "fatalities reported" column of Table 11.

To calculate the fatality frequency rate (number of fatalities per million hours worked) an assumption of the number hours worked by a miner is needed. Given the informality and seasonal dynamics of ASM as well as to account for the fact that miners often interlock livelihoods with activities such as farming, the model used an average number of hours worked per year (Table 10). This was calculated based on a range of project and published data regarding seasonality and rural livelihood patterns (ILO 1999; Pact 2015; Dreschler 2001; Hentschel, Hruschka, and Priester 2002; Mwaipopo 2004; Kühn 2017; Barreto 2018; Republic of Sierra Leone 2018; Chupezi, Ingram, and Schure 2009).

TABLE 10. **Fatality Frequency Rates Model Assumptions**

2,000	hours worked per year for full-time ASM
1,000	hours worked per year for part-time/seasonal ASM
35%	estimate of global ASM workforce that is part-time/seasonal
1,650	**hours worked per year for average ASM**

TABLE 11. **Calculation of Fatality Frequency Rates using ILO Data from 1999**

	Fatalities reported				Fatality Frequency Rate (FFR)			
Country	**Range**	**Lower limit**	**Upper limit**	**Number of minors** (low-high)	**Lowest** (Low Fatality, High # Miners)	**Low** (Low Fatality, Low # Miners)	**High** (High Fatality, High # Miners)	**Highest** (High Fatality, Low # Miners)
Bolivia	>40	40	44	100,000	0.24	0.24	0.27	0.27
Chile	10-24	10	24	6,000-12,000	0.51	1.01	1.21	2.42
China	>6,000	6,000	6,499	4,300,000	0.85	0.85	0.92	0.92
Cuba	±1	0	2	5,000	0.00	0.00	0.24	0.24
Dominica	±1	0	2	125	0.00	0.00	9.70	9.70
Ghana	5->20	5	24	50,000-300,000	0.01	0.06	0.05	0.29
Guinea	±15	0	30	40,000	0.00	0.00	0.45	0.45

Guyana	±2	0	4	10,000-20,000	0.00	0.00	0.12	0.24
India	15-50	15	50	1,000,000-1,100,000	0.01	0.01	0.03	0.03
Kenya	±5	0	10	30,000-40,000	0.00	0.00	0.15	0.20
Malaysia	±2	0	4	4,600	0.00	0.00	0.53	0.53
Mexico	5-18	5	18	20,000-40,000	0.08	0.15	0.27	0.55
Myanmar	0-5	0	5	14,000	0.00	0.00	0.22	0.22
Namibia	±3	0	6	5,000-10,000	0.00	0.00	0.36	0.73
Nepal	1-3	1	3	500	1.21	1.21	3.64	3.64
Niger	0-27	0	27	440,000	0.00	0.00	0.04	0.04
Pakistan	45-90	45	90	90,000-370,000	0.07	0.30	0.15	0.61
Peru	±7	0	14	25,000-50,000	0.00	0.00	0.17	0.34
South Africa	±10	0	20	10,000	0.00	0.00	1.21	1.21
Tanzania	10-100	10	100	450,000-600,000	0.01	0.01	0.10	0.13
Thailand	<10	0	9	21,500	0.00	0.00	0.25	0.25
Zambia	5-7	5	7	20,000-30,000	0.10	0.15	0.14	0.21
Zimbabwe	10-30	10	44	50,000-350,000	0.02	0.12	0.05	0.36
Total	**-**	**6,146**	**7,022**	**6,691,725-7,857,725**	**0.47**	**0.56**	**0.54**	**0.64**

Source: Adapted from ILO (1999, 14).

REFERENCES

Barreto, ML, Schein, P, Hinton, J & Hruschka, F. 2018. *Economic contributions of artisanal and small-scale mining in Kenya: Gold and gemstones*. East Africa Research Fund, Department for International Development.

Chupezi, T.J., Ingram, V., and Schure, S. 2009. *Impacts of artisanal gold and diamond mining on livelihoods and the environment in the Sangha Tri-National Park landscape*. Center for International Forestry Research: Indonesia.

Dreschler, B. 2001. *Small-scale Mining and Sustainable Development within the SADC Region*. Minerals Mining and Sustainable Development. International Institute of Environment and Development.

Hentschel, T., Hruschka, F., and Priester, M. 2002. *Global Report on Artisanal and Small-Scale Mining*. Mining, Minerals and Sustainable Development Project Working Paper No. 70. London: International Institute for Environment and Development.