

## WHY SLIPS, TRIPS, AND FALLS ARE STILL A PROBLEM: A HAZARD ASSESSMENT AT SURFACE MINES

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Slips, trips, and falls (STF) contribute significantly to nonfatal incidents at surface mines. Although fall fatalities and STF from mobile equipment have been investigated, nonfatal incidents and STF hazards encountered at mines are not well documented. This paper aims to identify occupations and activities associated with nonfatal STF incidents at surface stone, sand, and gravel mines, document through a systematic observation the STF hazards encountered, and corroborate the findings of the hazard assessment using an analysis of nonfatal injury narratives reported in the Mine Safety and Health Administration (MSHA) injury database. Mobile equipment operators, laborers/utility men, and mechanics were most often involved in nonfatal STF incidents. Walking/running, getting on/off equipment, machine maintenance and repair, and handling supplies and materials accounted for over 80% of the activities being performed at the time of the incident. Solid debris, in the form of rocks and stones on unpaved surfaces and material accumulation on paved surfaces, and liquid contaminants, primarily pooled water, were common hazards identified during the systematic observation. Stair tread issues and transitions to and from ladders were also identified as hazards. These findings were in line with injury data where rocks, ice/snow, uneven ground, water, hoses, mud, and loose/unstable material were the most common contaminants and hazards encountered at the time of the incident. In addition, several recommendations are provided to help eliminate or remediate the identified hazards.

### INTRODUCTION

Slips, trips, and falls (STF) are a common problem in the surface mining industry. The Mine Safety and Health Administration (MSHA) accident, illness, and injury data indicates that STFs are the second leading cause of nonfatal incidents. In addition, falls also contribute to about 11% of fatalities in the mining industry (Nasarwanji, 2016). Each nonfatal slip without a fall costs on average \$33,500, and with a fall to the lower level costing on average \$50,000—median values of \$2,000 and \$2,800, respectively (NIOSH, 2018). The high prevalence of STF incidents and the large cost associated with these injuries warrant a closer look at STFs in the mining industry.

Over the past few years researchers at the National Institute for Occupational Safety and Health (NIOSH) have examined slips, trips, and falls in mining. Nasarwanji (2016) reported on activities, occupations, and contributing factors associated with fall-related fatalities. In addition, others have investigated and have reported on STF incidents from mobile equipment (Moore, Porter, & Dempsey, 2009; Nasarwanji, Pollard, & Porter, 2018; Santos, Porter, & Mayton, 2010). Nevertheless, STF hazards, encountered as part of daily activities that lead to nonfatal incidents and near-miss events, have not been adequately addressed.

Radomsky, Ramani, & Flick (2001) provide a summary of STF hazards in mining and strategies to reduce them. However, their work was not based on an assessment of hazards and relied on the authors' expertise and experience. Bell, Gardner, & Landsittel (2000) investigated STF risks associated with cold environmental conditions at surface mines. However, STF hazards at surface stone, sand, and gravel (SSG) mines are not yet documented. In addition, occupations at risk for nonfatal incidents and their associated activities have not been sufficiently documented for surface mining operations.

The goal of this paper is to report on occupations and activities which pose a risk for nonfatal STF incidents at surface SSG mines and to present a systematic assessment of STF hazards encountered at these mines.

### METHODS

#### Analysis of MSHA nonfatal injury data

The first phase of the analysis was to help identify which occupations and activities are at a high risk for STF incidents. We analyzed three years of nonfatal STF incidents published by MSHA from 2015–2017 (Mine Safety and Health Administration, 2015–2017). Only three years of data were used to identify occupations and activities as analysis of occupational fatalities and nonfatal incidents in mining have shown little variation between years (Moore et al., 2009; Nasarwanji et al., 2018; Reardon, Heberger, & Dempsey, 2014; Weston, Nasarwanji, & Pollard, 2016). As there can potentially be differences among commodities, we focused our efforts on SSG mine operators only. Contractors were excluded from the study as they are often hired for specific tasks and activities and including them may bias the activities associated with the nonfatal STF incidents at SSG mines. Nonfatal STF incidents were selected based on pre-coded variables in the MSHA accident, injury, and illness dataset, including the nature of injury (nonfatal), accident injury classification (slips), and accident type (falls). Occupations and activities were identified based on the official job title and reported mine worker activity at the time of the event.

#### STF hazard assessment

Phase two of the study involved quantifying the number of times specific STF hazards were encountered at surface SSG mines. Two tandem approaches were adopted to create a preliminary hazard list: 1) identify STF hazards included in 30 Code of Federal Regulations (CFR) that are used to regulate the mining industry and other industry standards such as 29

CFR, ASTM F1637-13, and ANSI A117.1-2009 and 2) compile a list of hazards based on multiple preliminary visits to SSG mines. Based on 30 CFR, STF issues were most often associated with housekeeping or travelways. Although specific hazards were not listed in 30 CFR, it provided guidance on the types of hazards that may lead to STF, such as mats being trip hazards, pooled water posing a slip hazard, and not wearing fall protection leading to fall injuries. Tours and visits to three surface sand and stone mines yielded a more detailed list of hazards. After combining the two lists, hazards were prioritized based on a risk priority number (RPN), which was evaluated by two researchers independently and then combined. The RPN was calculated by combining subjective assessments of the likelihood of encountering the hazard and the severity of potential injury. Hazards with high RPNs were selected for the STF hazard assessment; however, hazards were limited to approximately 10 per surface to ease assessment based on pilot testing. The final STF hazard list included 11 hazards on walkways, 9 hazards on stairways, and 7 hazards on ladders (details provided in the following results section). For the purpose of this study, a walkway was defined as a surface the mine worker has to traverse—paved, unpaved, indoors, outdoors—as part of activities conducted at the mine.

To quantify STF hazards encountered at surface SSG mines, we conducted systematic observations while shadowing mine workers as they conducted their routine work activities (McDonald, 2005). We shadowed a total of 8 mine workers (participants) from one sand mine and three crushed stone mines in Western Pennsylvania and Virginia for a total of 35 hours and 55 minutes (average 8 hours 58 minutes per site, and 4 hours 29 minutes per participant). Due to the limited shadowing time at each mine only pooled data is reported across the four sites. Participants were shadowed during all three shifts, but most of the shadowing was carried out during the first/day shift from early morning until late afternoon/early evening, the time during which most maintenance workers and laborers work. Each hazard was recorded when encountered for the three areas of interest: walkways, stairways, and ladder.

Approximately 70% of the shadowing was during dry and sunny or cloudy conditions, about 11% when it was raining or had just rained, and about 19% when it was snowing or had just snowed. In addition, the ambient temperature varied from 0°C to 23°C with an average of 11°C. Although the hazard assessment was conducted from August to November, conditions represent average seasonal variations at the mine sites visited.

**Analysis of MSHA nonfatal injury narratives**

The final phase of the analysis focused on corroborating the findings of the STF hazard assessment by identifying hazards that are documented to contribute to STF incidents. We analyzed all 431 narrative descriptions of nonfatal STF incidents reported to MSHA in 2017 from the accident, injury, and illness dataset (Mine Safety and Health Administration, 2017). Each record was read and manually coded by the first author to categorize the type of event which led to the incident. These included any slip, trip, step on, unexpected movement, failure, lost balance, or other event and any

reported contaminants on the surface or other hazards which may have contributed to the STF event (e.g. water, snow/ice, mud, rocks, hoses, etc.).

**RESULTS**

**Analysis of MSHA nonfatal injury data**

Over the three-year period of interest, nonfatal STF incidents at SSG mines accounted for a total of 1,339 incidents (22% of all reported nonfatal injuries) or on average 446 incidents per year. Five primary occupations were involved in nearly 79% of all reported STF incidents, including mobile equipment operators, laborers/utility workers, mechanics (including electricians and welders), warehousemen, and foremen/managers/supervisors (Figure 1). Mobile equipment operators included those that operate front end loaders, haul trucks, dozers, backhoes, trackhoes, cranes, forklifts, scrapers, graders, and water trucks. Warehousemen included bagger, palletizer/stacker, storekeeper, packager, fabricator, and cleaning plant operator. When considering activities at the time of the STF incident, 82% of all incidents occurred when performing only four activities: walking/running, getting on/off equipment, machine maintenance and repair, and handling supplies and materials (Figure 2).

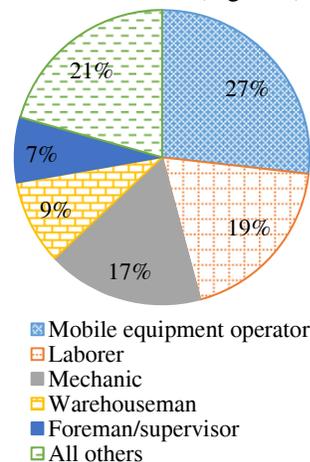


Figure 1: Occupations associated with STF incidents at surface SSG mines from 2015 through 2017.

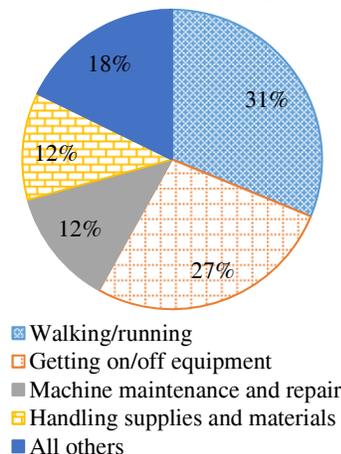


Figure 2: Activities at the time of STF incidents at surface SSG mines from 2015 through 2017

**STF hazard assessment**

Based on the findings of the nonfatal injury analysis from phase one of the study, we focused our STF hazard assessment on mechanics and laborers. In these occupations, workers are more likely to walk around and work in different areas as compared to mobile equipment operators. There is already considerable research on mobile-equipment-related injuries in the mining industry (Drury, Porter, & Dempsey, 2012; Moore et al., 2009; Santos et al., 2010), where slips and falls when getting on and off equipment has been studied as a key concern (Nasarwanji, 2016; Moore et al., 2009; Santos et al., 2010).

The eight participants included five maintenance workers, one mechanic, one electrician, and one laborer/utility worker. The primary tasks performed by the participants included inspection of conveyors, screen decks, and crushers and hosing out debris under screen decks and crushers. Other tasks observed were greasing conveyors, removing debris from grated metal walkways along conveyors, replacing screens, fixing and reassembling pumps, reassembling a cone crusher torn down for maintenance, fixing a water line, hosing out hoppers at the end of the shift, replacing equipment sensors, de-icing hoses, and clearing snow from conveyors, tail pulleys, and take-up pulleys. When asked, participants responded that the tasks and environmental conditions were similar to what would be commonly encountered as part of their daily duties during this time of year.

Table 1 shows the number of times specific walkway hazards were encountered during the approximate 36-hour shadowing period. Most common hazards were solid debris or liquid contaminants on the surface. Solid debris included rocks and stones on unpaved surfaces and material accumulation on paved surfaces. Liquid contaminants primarily included pooled water but also included oil and other liquids. Other common hazards included changes in the level of the walking surface of more than a half inch due to heaving ground and at transitions from unpaved to paved surfaces, trip hazards like hoses and pipes, snow and ice on the walkway, and a single step up or down.

Participants encountered 185 stairways during the shadowing period. About 30% of the stairways have some tread-related issues, including bent or damaged treads, inconsistent tread spacing, or a bottom or top tread not level with the landing (Table 2). Solid debris, including rocks and accumulation was encountered on about 25% of the stairways. Liquid contaminants, including pooled water and other liquids such as oil, were encountered 12% of the time. Worn surfaces and missing guardrails were not encountered.

Participants encountered 26 ladders during the shadowing period. Compromised transitions—which were defined as the ground not level, debris, or liquid at base or top of the ladder, and broken, bent, or damaged top or bottom rungs—were encountered on 71% of ladders. The high proportion of ladders with compromised transitions was primarily due to ladders with a lower landing on unpaved ground, which were either eroded or had material accumulation build up or pooled water. Ladder rung issues, including bent rungs, were observed 7% of the time. Although included in the assessment, other hazards, such as solid debris

and liquid contaminants on ladders, unsecured or worn ladders, and missing safety barriers at the top of ladders, were not observed during the shadowing period.

*Table 1: Number of times observable hazards were encountered on walkways during the approximate 36-hour shadowing period*

Observable hazard	Number of times hazard encountered (n)	Calculated duration between encounters (min)
Solid debris*	576	3.7
Liquid contaminants*	469	4.6
Change in level	260	8.3
Trip hazards	159	13.4
Snow/Ice*	135	16.0
Single step up/down	131	16.5
Low vertical clearance	67	32.2
Unsecured surface	17	126.8
Guardrail missing	9	239.4
Surface worn	6	359.7
Floor opening	1	2,155

\*Conservative estimate as the hazard was only recorded once for each walkway surface encountered (multiple hazards may be present on the same surface).

*Table 2: Number of times observable hazards were encountered on the 185 stairways encountered during the approximately 36-hour shadowing period*

Observable hazard	Number of times hazard encountered (n)	Average proportion of stairways with hazard
Tread issues*	55	29.7%
Solid debris*	47	25.4%
Liquid contaminants*	23	12.4%
Low vertical clearance	8	4.3%
Doors open onto stairs	8	4.3%
Surface unsecured	7	3.8%
Trip hazards	4	2.2%

\*Conservative estimate as the hazard was only recorded once for each stairway encountered (multiple hazards may be present on the same stairway)

**Analysis of MSHA nonfatal injury narratives**

Figure 3 shows the various events, identified from the narratives, which led to STFs. Slips were the most common event occurring in about 37% of the 431 STF-related narratives reported to MSHA in 2017. Other events included trips, step on/in, movement, and failure. A surprisingly high number of narratives were categorized as “unspecific” (11%)—defined as an incident that occurs spontaneously or for which the root cause is unspecified—where the incidents were commonly described as “employee sprained ankle while walking,” “the employee’s knee popped as he turned,” or “employee felt pain (in the knee, back, or ankle).” Movement and failure was most often due to unexpected movement of equipment or unexpected failure of equipment. Tools,

conveyors, and mobile equipment were items that moved unexpectedly. Similarly, tools, doors, and guards were what failed most commonly. All slip or trip events do not necessarily lead to falls. Based on our analysis of the data reported to MSHA in 2017, about 65% of STF events were falls (Mine Safety and Health Administration, 2017). Our analysis of STF narratives indicated a similar result. Only 60% of the STF narratives explicitly reported that the employee fell.

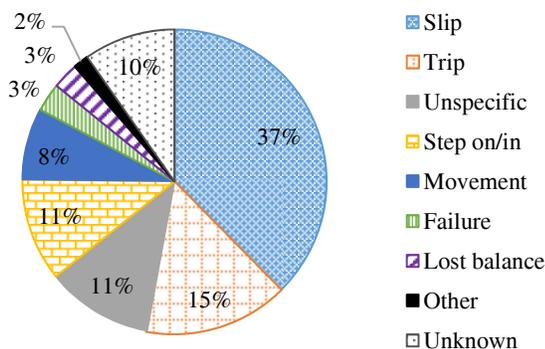


Figure 3: Events that led to STF incidents.

Specific contaminants and hazards were only explicitly reported in 30% of the narratives. When reported, rocks (n=20), ice/snow (n=19), uneven ground (n=14), water (n=14), hoses (n=12), mud (n=11), and loose/unstable material (n=10) were the most common contaminants and hazards. For slip events, ice/snow (n=16), water (n=11), mud (n=11), rocks (n=6), and loose/unstable material (n=6) were the most common contaminants. For trip events, hoses, cables, and wires (n=14) were the leading hazard, followed by items on the ground such as pallets (n=6), rocks (n=3), and boxes (n=2). Step-on events led to injuries most often due to uneven ground (n=12), rocks (n=6), holes (n=4), and material accumulation (n=3). Carrying/holding items in the hand, inadequate illumination, and wind were some of the other contributing factors to STF incidents.

### DISCUSSION

The objective of this work was to identify STF hazards in the SSG mining industry and to identify the occupations and activities commonly associated with STF events. The STF hazards identified are consistent with those likely to be encountered when working outdoors on primarily unpaved surfaces. Rocks and stones on unpaved surfaces, uneven ground, mud, and loose material accumulation were some STF hazards documented through observation and analysis of injury narratives. Although paving all walking surfaces and keeping them free from contaminants would be the ideal solution, due to the large area occupied by mines sites it would be impractical in mining. Instead, providing designated walkways that are kept free of contaminants is a viable option. Observations revealed that during normal operations, mine workers take predictable paths between buildings, sheds, screen decks, and crushers. These paths could be designated as walkways and where attention should be focused to ensure the

walkways are free from any debris and liquid contaminants. Designated walkways could be raised to limit the accumulation of water and constructed of gravel, grated metal (materials commonly used at mines), or paved. Grading, a technique commonly used to level uneven roadways at mines, should be adopted as a last resort to keep unpaved walkways free from ruts and uneven ground.

Liquid contaminants, especially pooled water and wet mud, also pose a significant STF hazard. Many SSG mines have water continuously flowing due to the wet process, for dust suppression, and to clear out material accumulation around conveyors, crushers, and other equipment. Runoff water is often directed to settling or catchment ponds; however, drainage may be inadequate. The continuous flow of water often leads to small puddles, ponds around crushers, and screen decks with streams and gullies from the settling and processing areas to the settling ponds. During the systematic observation period, streams and gullies were regularly observed to be in the path of travel. Attempts should be made, when designing SSG crushing and processing areas, to account for the large amount of water used and design appropriate drainage. In the interim, small bridges made of grated metal could be used to cross these gullies, or the gullies could be diverted away from the path of travel. Trip hazards such as hoses and cables were also common. Basic housekeeping and good safety practices should be encouraged to mitigate these hazards.

Conditions that could lead to slips were observed often during shadowing. However slip events only accounted for 37% of STF incidents. This could be attributed to a combination of likelihood of encountering the hazard and the severity of potential injury. Slip hazards although encountered often, may not lead to reportable injuries as often. In comparison, although other hazards such as unsecure surfaces, and missing guardrails are not observed as often, they may lead to reportable injuries potentially due to the severity of the outcome.

Other than solid debris and liquid contaminants identified on stairs, most hazards on stairs and ladders can be attributed to the design or inadequate maintenance to combat wear. Stairs can get easily damaged and bent when moving heavy material and equipment up and down them. In these instances, the treads should be bent back into place or promptly replaced. Inconsistent tread spacing, a bottom or top tread not level with the landing, and transition issues on ladders (from eroded material or pooled liquid at the base) are often due to inadequate design, or a lack of maintenance. Adequate landings and uniform tread spacing from the first through the last step or rung should be provided. Injury narratives did not provide any additional detail on stair and ladder hazards, but a closer look at the MSHA data from 2015–2017 indicated that falls from stairs or ladders accounted for about 7.3% of all STF incidents at surface SSG mines.

A previous study of fall fatalities in the mining industry indicated that working at heights with missing barriers or inappropriate use of fall protection were the most common contributing factors related to these events (Nasarwanji, 2016). Our hazard assessment revealed that missing guardrails and

floor openings, through which individuals could fall, were not encountered often during routine activities. Missing guardrails and floor openings may be encountered more often in nonroutine or unplanned activities such as maintenance and repair. In addition, unplanned activities, such as maintenance and repair, are shown to pose a higher risk to mine workers (Reardon, Heberger, & Dempsey, 2014). Hence, known hazards associated with working at heights should not be ignored due to the severity associated with the potential outcomes and the known risk.

Occupations identified here for nonfatal STF incidents are similar to those for fall fatalities (Nasarwanji, 2016). Mechanics, laborers, and equipment operators were the top three occupations associated with fall fatalities and nonfatal incidents. Considering that data from multiple sources point to similar occupations, it is prudent to focus STF prevention efforts on these occupations. Walking and running, getting on and off equipment, and maintenance and repair were the most common activities for nonfatal incidents. In comparison, maintenance and repair was the main activity for fatal incidents (Nasarwanji, 2016). This analysis included incidents that did not lead to falls as well as those that did. In comparison, fatal incidents analyzed previously were only associated with falls (Nasarwanji, 2016). Even after accounting for these differences, hazards that cause nonfatal and fatal STF-related incidents in the surface SSG mining industry may be different. Nonfatal incidents can be largely attributed to surface contaminants and hazards in comparison to fatal incidents which are largely due to working at heights (Nasarwanji, 2016).

### LIMITATIONS

The limited sample is one of the shortcomings of the work conducted in this study. STF narratives were only analyzed for one year by one author to corroborate the STF hazard assessment. One year of injury narratives yielded 431 cases which was adequate to identify both common activities and common contaminants associated with the STF incidents. The overall shadowing time was only about one week. However, efforts were made to mirror seasonal trends, and most participants indicated that environments and activities observed were representative of normal work. Although we did observe the reconstruction of a crusher, this analysis may not be representative of other unexpected or planned circumstances, such as the breakdown of equipment or scheduled maintenance, respectively. Finally, the hazard assessment was limited to surface SSG mines in the northeast United States.

### CONCLUSIONS

Because there is a lack of information on STF hazards at surface mines, this study documented, through observation and the analysis of injury data, STF hazards at surface SSG mines. In addition, occupations at risk and activities associated with nonfatal STF events were documented. There are remedial measures that can be taken to eliminate or minimize exposure to the identified hazards. These should be considered to reduce the burden associated with STF incidents at surface mining operations.

### ACKNOWLEDGEMENTS & DISCLAIMER

The authors would like to thank William Porter, Ashley Whitson, and Lydia Kocher for assistance developing the list of hazards.

The findings and conclusions in this paper are those of the authors and do not necessarily represent the official position of the National Institute for Occupational Safety and Health (NIOSH), Centers for Disease Control and Prevention. Mention of any company or product does not constitute endorsement by NIOSH.

### REFERENCES

- Bell, J. L., Gardner, L. I., & Landsittel, D. P. (2000). Slip and fall-related injuries in relation to environmental cold and work location in above-ground coal mining operations. *American Journal of Industrial Medicine*, 38(1), 40-48.
- Drury, C. G., Porter, W. L., & Dempsey, P. G. (2012). Patterns in Mining Haul Truck Accidents. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 56(1), 2011-2015.
- McDonald, S. J. Q. r. (2005). Studying actions in context: a qualitative shadowing method for organizational research. 5(4), 455-473.
- Mine Safety and Health Administration. (2015-2017). Mining Industry Accident, Injuries, Employment, and Production Statistics and Reports. Retrieved from <http://www.cdc.gov/niosh/mining/data/default.html>
- Moore, S. M., Porter, W. L., & Dempsey, P. G. (2009). Fall from equipment injuries in U.S. mining: Identification of specific research areas for future investigation. *Journal of Safety Research*, 40(6), 455-460.
- Nasarwanji, M. F. (2016). Contributing factors to slip, trip, and fall fatalities at surface coal and metal/nonmetal mines. In Proceedings of the Human Factors and Ergonomics Society Annual Meeting (Vol. 60, No. 1, pp. 1666-1670). Sage Publications.
- Nasarwanji, M. F., Pollard, J., & Porter, W. (2018). An analysis of injuries to front-end loader operators during ingress and egress. *International journal of industrial ergonomics*, 62, 84-92.
- NIOSH. (2018). Safety Pays in Mining. Retrieved from <https://www.cdc.gov/niosh/mining/content/economics/safetypays.html>
- Radomsky, M. C., Ramani, R. V., & Flick, J. P. (2001). Slips, Trips & Falls in Construction & Mining: Causes & Controls. *Professional Safety*, 46(9), 30-37.
- Reardon, L. M., Heberger, J. R., & Dempsey, P. G. (2014). Analysis of Fatalities During Maintenance and Repair Operations in the U.S. Mining Sector. *IIE Transactions on Occupational Ergonomics and Human Factors*, 2(1), 27-38.
- Santos, B. R., Porter, W. L., & Mayton, A. G. (2010). An Analysis of Injuries to Haul Truck Operators in the U.S. Mining Industry. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 54(21), 1870-1874.
- Weston, E., Nasarwanji, M. F., & Pollard, J. P. (2016). Identification of Work-Related Musculoskeletal Disorders in Mining. *Journal of safety, health and environmental research*, 12(1), 274-283.