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Landfill Operations and Off Highway Construction Vehicle Visibility Impairment Issues Result in a Serious Injury: A Case Study

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Abstract

This case study reviews the hazards involved with the work procedures and work environment combined with large mobile equipment associated with a landfill operation. An active landfill is a very busy work environment. There typically is a constant stream of municipal solid waste (MSW) trucks of various sizes and dimensions approaching and dropping their waste load onto the landfill active work area, which is referred to as the landfill face or tipping area. In addition to the MSW delivery truck traffic, the active face in this case study was being traversed back and forth by two large industrial vehicles: a bulldozer (or "dozer") and a steel-wheeled compactor vehicle. The injured party, who was just transferred to the job of "waste spotter," or just spotter, had the responsibility of directing the incoming stream of MSW trucks as to where to dump their loads while also directing (and avoiding) the tracked loader and the steel-wheeled compactor vehicle as they operated on the landfill active face. Additionally, due to the dumped MSW, the active landfill face topography is constantly changing, and the pedestrian spotter therefore must constantly be moving on the active face to avoid being struck by the vehicular traffic. The bulldozer manufacturer acknowledged that the loader travels in reverse approximately 50 percent of its operating time on the landfill space. Hence, any static visibility impairments were further compounded when the dozer traveled in reverse over changing topography. Other issues that negatively affected the landfill face hazardous environment were a lack of any safety procedures for the landfill operations and a lack of hazard training and instructions provided to the waste spotter working the landfill face.

Keywords

Landfill training, spotter, crawler, bulldozer, loader, compactor, visibility, midden, tipping area

Purpose

This paper hopes to introduce readers to some of the many hazards involved in the operation of a landfill. Additionally, it will be shown that the necessity for proper safety, planning, and training for all phases of landfill operations cannot be overemphasized. Also addressed will be the need for providing adequate operator visibility in both the forward and reverse directions of large vehicles working on the landfill face. These vehicles include specifically large bulldozers and steel-wheeled compactors. The topic of the necessity for regular and ongoing communication among all people working the landfill space (including the spotter and all drivers and machine operators working on the landfill face) will be discussed.

Introduction

This case study involves the assessment of a serious worker injury that occurred on the active face of a landfill. The term landfill is presently also known as a tip dumping ground, garbage dump, and rubbish dump. Historically, landfills were known as middens. Indeed, middens are presently utilized by archaeologists to study the living and dietary habits of previous generations. Landfills are often the most cost-efficient way for organized waste disposal by designed burial of waste material. Modern landfills are benefiting from modern study and technology and are subject to various regulations. The landfill and/or rubbish dump active face is that location where the trash or garbage trucks of different sizes and configurations bring and dump their loads for delivery to the landfill active face and then leave the area. In addition to the garbage truck traffic entering the landfill active face, compactors (steel-wheeled vehicles) and/or bulldozers are used to spread and compact the deposited waste on the working face. The machines working the active face will typically make three to five passes over a single area in different directions (both forward and reverse) to assure proper compaction of the waste material (Walsh et. al. 2002). Compactors are steel-wheeled vehicles whose wheels are studded with various designs of steel load concentrators or studs. They are utilized to maximize waste compaction and are typically found on medium to large sites that can

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support more than one machine working the active face.

Bulldozers (also known as dozers and crawler tractors) and crawler loaders are track type vehicles that are also utilized to compact waste, but also serve in relocating waste on the active face as well as face cover application and excavation (Walsh et. al 2002). The tracked vehicle's freedom of movement — and its designed function of moving and flattening materials, often in tight quarters — requires that these vehicles travel in reverse approximately half the time. This situation is further exacerbated due to its large size, which causes the operator to lose some of his visibility when driving forward and even more so when traveling in reverse. Thus, when traveling in reverse, the machine operator (attempting to observe traffic, pedestrians, obstructions, etc.) must turn in his seat and continually look over his shoulders, typically an industry-suggested practice. Therefore, the range of operator visibility while operating the vehicle deteriorates due to driver fatigue, stress, neck and back pain, or any combination of these factors. Further visibility deterioration is generated when the vehicle must traverse hills of trash while traveling in reverse. Traveling in reverse accounts for at least 50 percent of fatalities from being run over by construction equipment (Pegula 2004). This physically demanding rear-view viewing approach is also applicable to other large industrial vehicles, such as large forklift trucks (Josephs 2003).

As the compressed waste starts to decompose, gases are produced by microbial anaerobic digestion of the waste. This gas, although "dirty," is primarily composed of methane and is typically collected and used. The gas collection uses a series of pipes buried within the landfill, with some pipes exiting the landfill surface. In this case study, there was a gas pipe located in the active face, which necessarily had to be avoided by vehicles.

Coordinating all this traffic on the landfill face is the "waste spotter." The spotter is responsible for directing the incoming garbage truck traffic to the active face and the compactor and dozer traffic to properly compact the waste — while at the same time trying to keep vehicular traffic on the active face away from any gas pipe.

The physical shape, geometry, and configuration of the active face are in a constant state of flux. The specific area that was previously a hillock of recently dumped garbage can become flattened and now present as a depression after a few passes of the compactor and dozer. It is apparent that being a landfill spotter presents numerous hazards due to the nature of the work, the constantly changing terrain, the types of vehicles, the vehicle traffic, and its changing direction in close proximity.

There are a far greater proportion of accidents and fatalities at landfills than in many other industries purely because of the nature of the work. Many accidents and injuries that are suffered by those who work within the industry are transport related (Durham 2013).

In 2015, the New York State Fatality Assessment and Control Evaluation (FACE) program reported:

"The EPA states that the number of landfills decreased substantially over the past years from nearly 8,000 in 1988 to 1,654 in 2005 ... while average landfill size increased. Although many town dumps had closed, they were replaced by fewer, but larger regional ones" (FACE 2015).

This, of course, indicates that the increasing number of larger regional landfills would require and therefore utilize larger types of construction vehicles in landfill applications with all the hazards that are associated with such vehicles.

Dr. Ross A. MacFarland of the Harvard School of Public Health is quoted in a 1964 SAE publication (Connolly et al 1964), stating the importance of the driver machine relationship by:

"*The human engineering approach to highway safety can be more effectively carried out when data on the capabilities and limitation of drivers are done; it is only a matter of time before some 'design failure' results in 'driver failure' and an accident.*"

This statement, written more than 50 years prior to the occurrence of this case study's injury accident, prophetically described the unfortunate serious injury accident resulting from a lack of a visibility-enhancing safety feature incorporated into initial vehicle design in view of operators' limitations and capabilities.

The Environmental Industry Association's 2001 *Manual of Recommended Safety Practices* provides a more specific statement describing workplace hazards where there is interaction between workers and motor vehicles in the work environment. Excerpts from this document are presented below:

"Overview of the Subject

Traffic through landfills, transfer stations material recovery facilities (MRFs) and at hauling operations can create hazardous work environments if they are not managed properly.

According to the Bureau of Labor Statistics, more than 2,000 deaths a year result from occupational motor vehicle incidents, more than 30% of the total annual number of fatalities from occupational injuries. These deaths include driver and passenger deaths in highway crashes, farm equipment accidents, and industrial vehicle incidents as well as pedestrian fatalities.

In an analysis of data for 1990-92, NIOSH found that the industries with the highest average annual rates of death per 100,000 from traffic-related motor vehicle crashes were:

- *Trucking (12.1 deaths per 100,000 workers), logging (9 deaths per 100,000 workers)*
- *Fuel dealers (5.6 deaths per 100,000 workers)*
- *Petroleum products (5.2 deaths per 100,000 workers)*
- *Agriculture crop production (4.2 deaths per 100,000 workers).*

Occupations with the highest annual average fatality rates per 100,000 workers were:

- *Truck driver (12.2 deaths per 100,000 workers)*
- *Garbage collector (11.5 deaths per 100,000 workers)*
- *Sheriff/bailiff (7.1 deaths per 100,000 workers)*
- *Farm worker supervisor (5.2 deaths per 100,000 workers), and*
- *Surveying and mapping technician (5.1 deaths per 100,000 workers).*

NIOSH found that from 1980 to 1992, motor vehicle crashes were the leading cause of work-related deaths in U.S. workers. During this period, traffic-related motor vehicle crashes accounted for the deaths of 15,830 workers — or 20% of all fatal workplace injuries. Also during that period, 1,997 worker deaths were associated with motor vehicle crashes that were not related to traffic on a public highway. The number of traffic-related deaths was eight times the number not related to traffic.

Duties and Responsibilities

Employers

Employers should develop and implement an appropriate traffic control plan for their facility operations. They must also provide supervision, through appropriate contract conditions, with a means to enforce the traffic plan with non-employee drivers (visitors).

Supervisors

Supervisors are responsible for implementing the employer's traffic control plan and enforcing employee/ visitor compliance with traffic speed limits and other traffic safety rules. In addition, supervisors should review traffic flow on a frequent basis to accommodate changing conditions such as wind, rain, sleet, snow, etc. (Legler et. al. 2001)

Busy construction sites, although entirely different from landfills, contain many of the same types of hazards. Hence, statistics of fatalities at road construction sites can shed some light on the hazards found when working on a landfill, due to the similarities of the hazards presented by large industrial equipment working and moving in the vicinity of otherwise occupied pedestrian workers.

Road construction workers face many hazards on the job. In addition to many of the hazards present on a "traditional" construction site, road workers also need to contend with moving vehicles — both in and around the job site. Road construction workers, like landfill workers, risk injury from construction equipment operating within work zones. From 1995 through 2002, 844 fatal occupational injuries occurred at road construction sites. The majority of these fatalities, 693 (82 percent) cases, were reported to be transportation incidents. Fatalities involving a ground worker being struck by a vehicle or equipment accounted for 509 (73 percent) of the transportation incidents. Victims were as likely to be struck by construction equipment (32 percent) as by highway vehicles (28 percent) (CDC 2011).

Scenario

A cement finisher who suffered a back injury was temporarily transferred to a "light work" job at a sister company in an interwoven number of corporations. This job consisted of being the "waste spotter" or "spotter" on an active landfill face. The transferred spotter received no training, reading materials, or instruction in the duties and potential hazards of being a spotter. His only instruction was to direct the vehicles on the landfill face to avoid striking a vertical gas pipe that protruded from the landfill surface. The vehicles involved in the landfill face traffic included:

- Trucks of various sizes and geometry continuously dumping trash and garbage on the face.
- A steel-wheeled compactor utilized for compacting the garbage and debris by making numerous forward

Figure 1
Accident site showing the steel-wheeled compactor and the gas vent pipe. Note the mounds of debris on the landfill face.

Figure 2
Close-up view of the steel-wheeled compactor and the gas vent pipe at the accident site.

and reverse "passes" over the mounds of heaped garbage and debris. The subject compactor at the accident site is shown in **Figures 1** and **2**.

- A crawler loader utilized for moving the trash/debris and compacting the trash and debris by making numerous back and forth passes.

Figure 3 shows the subject crawler loader at the accident site. The loader was being operated that day by a replacement operator who received no training in the safe operation of the loader on the landfill face. The loader, while traveling in reverse over a hillock of trash, struck and seriously injured the trash spotter. The incident was observed and witnessed by a truck driver delivering trash to the site. Other workers who observed the incident stood by in apparent disbelief/shock and offered no assistance. The injured worker himself called 911, describing his injury and requesting a heli-vac transfer to the closest hospital while drifting in and out of consciousness. The injured worker lost both legs so close to his hip that he was not a candidate for prosthetic surgery.

At the day and time of the injury accident, the spotter was not wearing any high-visibility clothing or vest but rather standard work clothes and a standard red-colored vest, but not a "dayglo" vest.

The subject crawler loader was equipped with the following:

- A fixed operator's seat facing forward.
- A single internal rearview mirror (no external mirrors).
- A constant level audio back-up alarm that sounded automatically when the vehicle traveled in reverse. The back-up alarm was mounted below a crossmember and behind a mounting plate that significantly reduced the back-up alarm audio output.
- A large vertical exhaust stack in the center of the rear of the vehicle.
- A "landfill package" as sold and provided by the manufacturer, indicating knowledge by the manufacturer of the ultimate use of the dozer.

Elements of Analysis

The primary focus of any landfill management team is succinctly stated below:

"… *Assuring the safety and well being of employees and running an efficient site that complies with all legal and environmental requirements are number-one priorities for the waste management team."* (Bliss 2006)

Figure 3
Subject crawler loader at the accident site.

However, with respect to this case study, there are a number of different hazard-related issues whose combination resulted in the serious injury accident. They can be conveniently represented by the following major task areas:

- Pre-Accident – Training and Instruction
- Work Environment – Landfill Face
- Task/Job – Waste Spotter
- Equipment – Large Moving Tracked and Wheeled Vehicles
- Post-accident – Training and Instruction

As noted earlier, the spotter was transferred from another corporate sister entity to the landfill for "light-duty" work while recuperating from a back injury. In this scenario, the waste spotter received absolutely no safety training or instruction with respect to the hazards involved when working on the landfill space. The spotter had never previously been on a landfill space and was not aware of any of the hazards involved in landfill operations in general and specifically, those involved in this landfill face. The employer did have a number of videos on general topics of workplace safety. However, even these videos, which addressed general issues of workplace safety, were not shown to the prospective waste spotter, nor did he know that they even existed. Indeed, his only specific instruction was to focus on the vertical gas vent located in the landfill face and to direct the landfill face traffic away from the pipe so that it would not be struck. Landfill management's directions with respect to maintaining the vent pipe structural integrity, as opposed to focusing on worker safety, contributed to the hazard elements on the work face.

The spotter was also not informed of the necessity for communicating by hand signals to direct the crawler loader and compactor operators. Additionally, even though the landfill operation had a person on staff identified as the landfill's "safety director," the person so identified admitted that he had no training in safety, that he was not really responsible for safety, and that indeed there was no knowledgeable individual in the company responsible for safety at the landfill operation at the time of the accident.

Work Environment – Landfill Face

The landfill did not have any written procedures or training to coordinate the equipment operators' work with that of the spotter or the delivery drivers who would often appear in the driver's blind spot as part of their work procedures. The working landfill face is in a constant state of activity, as the debris and waste are being brought by the incoming garbage trucks dumping garbage, the crawler loaders are moving and compacting the material, and the wheeled compactors are compacting the material. Hence, while performing his duties of directing the vehicular traffic on the landfill face, the free-ranging pedestrian waste spotter had to avoid being struck by the vehicular traffic in his relatively small work location. Additionally, as the material is dumped by the stream of incoming garbage trucks, small hills of debris are created, which can conceal the location and direction of motion of the tracked and wheeled vehicles working the face.

As the vehicles move and compact the material, the vehicles move up and down while going over the garbage mounds. The driver's field of vision can be severely obscured depending upon the orientation of the vehicle as the vehicle tilts upward or downward on the mounds. This compounds the visibility impairments created by the vehicle's large size. **Figure 4** depicts a generic bulldozer (equipped with a moldboard for pushing and back-dragging material) and its orientation while working on the landfill face. Additionally, this figure demonstrates the significant reduction in the operator's field of vision due to the typical operation of a crawler tractor on a landfill face.

There are numerous stressors that could cause the spotter to be distracted and therefore not be fully cognizant of the moving vehicle hazards in his proximity including:

Noise: The landfill face is a high noise environment given the close proximity of the constant back and forth traffic of large off highway diesel powered equipment. The noise level is exacerbated by the constant sound level back-up alarm, which is part of the

Figure 4
Generic-type bulldozer showing typical orientation while working on the landfill face. Note the reduction in visibility due to traveling over the trash mounds.

cacophony of sound on the landfill face.

Slip and trip: The varying types and configuration of the debris on the landfill face can cause the spotter to be distracted due to the slip and trip hazards they represent. This is further exacerbated by the constantly moving and shifting of these hazards as the landfill face is constantly being changed and modified.

Cuts and punctures: Much of the debris on the landfill space has sharp edges protruding from the landfill face surface or lying about. In addition, the presence, location, orientation, and type of sharp or pointed edged surfaces change as the landfill face changes.

Dust: The dust raised by both the crawler loader and the steel-wheeled compactor could cause stressors that diminish the spotter's attention to his hazardous surroundings.

Structure or physical formation: There may be occasions in given landfills where some structure or other physical formation in or near the landfill face requires special attention from the spotter during operations. In this case study, the spotter was directed to make sure that the moving equipment did not strike the vertically exposed gas vent pipe. This caused an additional stressor that somewhat diminished the spotter's attention to the moving hazards in his changing work environment.

Task/Job

The spotter is required to work in a hazardous environment that is ever changing with respect to the type and location of the moving vehicle hazard but also in the very configuration and shape of the workplace itself (i.e., the landfill face or the tip). The major effort involved in maintaining a safe work environment on the landfill face is for the spotter or any other workers on the landfill face to "see and be seen." That is, the spotter must see and observe all the moving vehicles in the landfill face, and similarly the spotter must be seen by the truck drivers and vehicle operators at all times. If the spotter were to turn his back to one vehicle while directing another, he would not be able to see any oncoming traffic. By the same token, if an off-highway vehicle is hidden by some trash (as it could be when traveling in reverse over a large trash mound), then the vehicle operator would not be able to see the spotter.

The landfill space, due to its many hazards, can be among the most hazardous of environments, yet the spotter in this case study was placed into this hazardous and changing environment with:

- No radio to communicate with the vehicle drivers.
- No direction or requirement for wearing high-visibility garments.
- No closed circuit TV (CCTV) system provided with the bulldozer, requiring the operator to essentially drive "blind" when traveling in reverse.
- Little knowledge of the workplace hazards.
- No instruction.
- No training.
- No established protocol for communicating with the waste spotter by hand signaling.

In addition, the corporate individual responsible for safety and training never had any safety training or specific knowledge of landfill face work hazards. He testified that there was no one in the corporate organization who was responsible or knowledgeable for the training and instruction of workers of the hazards involved in working on a landfill face.

Equipment

The other factor involved in this hazard analysis is the equipment that is utilized on a daily basis on the landfill face. In the instant case, there were two specific pieces of equipment working the landfill face: a steel-wheeled compactor and a bulldozer. Because of the size of the bulldozer, the driver's blind spot in a static mode could be as much as 35 feet behind the driver if indeed he were looking in that specific direction. **Figures 5, 6**, and **7** show the size of the vehicle relative to a nearby pedestrian worker.

Figure 5
Left oblique static blind zone as depicted by the standing individual, who is invisible to the operator.

In all these figures, the individual outside the bulldozer is invisible to the loader operator.

The bulldozer manufacturer indicated that visibility tests of the bulldozer are performed. However, this testing is performed in a purely static manner, using light sources to represent the operator's eyes and the shadow created by the blockages associated with the vehicle, such as door posts and mufflers to represent the blind area thereby creating a blind-area diagram (ISO 5006 2006).

In 2001, NIOSH began developing and evaluating interventions to reduce the number of ground workers being struck by road construction equipment.

NIOSH had blind-area diagrams developed for three different planes: ground level, 900 mm (36 inches) above ground, and 1,500 mm (59 inches) above ground. The blind area associated with each plane corresponds to the area at which an object on that plane cannot be seen from the operator's position. The 900-mm plane was chosen because it represents the height of a construction barrel. The 1,500 mm plane is slightly less than the shoulder height of 95 percent of the U.S. adult female population, representing the height at which enough of the head is visible for an operator to recognize a person (CDC 2011).

Figure 6
Rear view static blind zone as depicted by the standing individual who is invisible to the operator. Note exhaust stack further limiting operator's rearward visibility.

When traveling in reverse, the bulldozer manufacturer suggested that the tracked vehicle operator perform a visual scan, first to look over one shoulder then at the centrally located in-cab mirror, and then to look down and backward — all this reverse traveling visual scan to be performed while the vehicle is traveling in reverse at approximately 10 ft/sec.

Since the subject bulldozer was sold with a specially installed "landfill package," the loader manufacturer knew at the time of sale of the specific intended use of the subject bulldozer.

Requiring an equipment operator to enhance his rearward visibility by looking backward over his shoulders requires the operator to resort to the energy-consuming and physiological stressful activity of turning his/her upper body, hips, and head alternatively in both directions. This suggested rearward viewing activity recommendation will quickly decrease as the work shift increases — fatigue increases as the operator's age increases or as the driver experiences increasing stress.

In contrast to the static visibility tests, driving a construction vehicle on the landfill face is obviously a dynamic activity. Driving the vehicle rearward creates a constantly changing visual environment for the operator, with people and/or vehicles entering or leaving his field of vision. To compensate for this constantly changing visual environment, one operator's manual recommends that the operator should continuously shift his shoulders and hips from side to side while alternately switching his head

Figure 7
Left view of bulldozer, showing static blind zone of pedestrian worker, who is invisible to the loader operator in the location shown.

position from one shoulder to the other as the dozer travels in reverse. This is clearly an imposition on human physiological capabilities that can seriously compromise safety of a laborer working at ground level.

It is foreseeable that off-highway vehicles working on landfills both in the forward and reverse direction will operate in noisy environments. Furthermore, the vehicles themselves are noisy. Tracked vehicles often are particularly noisy because of track noise. Hence, a bulldozer traveling in reverse using both a fixed sound level beeper and a flashing beacon to indicate its approaching presence is foreseeably obscured to busy and otherwise occupied workers who are facing away from the vehicle.

The subject bulldozer was not equipped with rear vision closed circuit TV systems. It had been reported as early as 1998 that rear vision camera technology was available to prevent the rear traveling blind spot as well as the common right side turning blind spot hazard (Browning and Simpson 1998).

The concern of the potential visual degradation of CCTV systems used in industrial environments caused by the raised dust and debris has been addressed by the National Mine Health and Safety Academy (MHSA), which, in 1999, proposed mandatory placement of video equipment on all surface mine haulage equipment (Reilly 1999). Additionally, the hazard created by the lack of CCTV systems for use with large industrial vehicles when traveling in reverse was addressed and previously published by this author for use on large forklift trucks (Josephs 2003).

Obviously, accidents will happen, especially in a hazardous place such as a landfill. Yet there was no instruction and/or training provided to the landfill employees as to what steps to follow in the event of an accident. Additionally, there was no target medical facility identified for the landfill employees with whom they could communicate and direct any of their questions and/or direct injured employees to a nearby hospital.

Analysis

There are three interrelated factors that affect the visibility of a construction vehicle operating on a landfill face (i.e., machine/environment/worker interface). The subject bulldozer was examined post-accident, and an attempt was made to determine the blind spots and blind zones of the vehicle while seated in the fixed forward-facing operator's seat. It was immediately apparent that the internally mounted rear-view mirror was woefully inadequate for providing any reasonable visibility for driving in reverse.

Variable blind zones were noted in a static mode in each vehicle direction. Rearward visibility was especially compromised wherein in some rearward directions a worker would not be visible until located approximately 40 feet from the bulldozer. In a dynamic mode, any attempt to look over one's shoulder to gain rearward visibility would immediately cause the other shoulder (or other side) to become totally blind and obscured. This one side developed blind zone was also created when the driver/operator would attempt to look down and back at hip level. Hence, following the manufacturer's scan procedure as a stratagem to gain rearward visibility would assure that at any given instant of time, one entire side of the vehicle would be totally hidden. Other types of large industrial vehicles also share this rearward traveling visibility issue, such as in large forklift trucks (Josephs 2003).

Environment

The construction vehicle rearward visibility deficits are even more pronounced when in a dynamic state (i.e., traveling in reverse on the landfill face). Here, the dozer is traveling in reverse (not necessarily in a straight line) over constantly changing terrain with the geometry of the terrain in a constant state of flux. Hence, an area that was previously a hillock may have been compressed to a depression, and what was previously a depressed area may now have a newly dumped truckload of waste, creating a small hill. Hence, the pitch of the loader can be constantly dipping up or down, which can further reduce its rearward visibility.

Worker

The dozer rearward visibility shortcomings are further amplified by the laborers and truck drivers working or present on the landfill face. Not only is the spotter moving about the landfill space, but also the delivery truck drivers will occasionally leave their trucks to perform some work-related task, such as cleaning their truck, replacing or retying cover tarps, or other covers, etc. While performing their tasks, any individual working on or near the landfill face can have his back facing the vehicles working the landfill face. In this case study, the spotter did have his back to the rearward traveling bulldozer when he was struck. In this case, therefore, neither the backward-facing spotter nor the operator of the rearward-traveling bulldozer saw each other, resulting in the serious accident. It is imperative that in order to maintain a minimum acceptable level of safety, it is necessary to maximize a "see

and be seen" rule. The "see and be seen" rule (SABS) is a safety engineering concept applied to many types of traveling vehicles. The SABS was presented and expanded upon by the author during years of teaching safety engineering. The "see and be seen" rule can be categorized as four separate components, as follows:

See and Be Seen Components		
Industrial Large Construction Vehicle Operator	**Pedestrian Worker (Spotter)**	**Relative Safety Range (4 is highest level)**
Equipment operator sees pedestrian worker	Spotter sees equipment	4
Equipment operator sees pedestrian worker	Spotter does not see equipment	3
Equipment operator does not and/or cannot see spotter	Spotter sees equipment	2
Equipment operator does not and/or cannot see spotter	Spotter does not and/or cannot see equipment	1

Each of the components of the "see and be seen" matrix can present a hazardous situation when considering the ongoing daily operations on the very busy and noisy landfill face. However, the most hazardous situation by far is that situation where neither the spotter nor the equipment operator see each other. This is that precise combination of hazardous events that led to this case study serious double amputation injury as described in this paper.

An obvious approach to enhance the "see and be seen" rule is for the worker to wear high-visibility garments. Until recently, there was a lack of definition in this regard. However, in 2009 OSHA clarified where workers are required to wear high-visibility garments in work zones wherein workers are exposed to the danger of being struck by vehicles operating in their vicinity. This construction work zone requirement is logically applicable and transferable to the landfill tip work zone.

Road and construction traffic poses an obvious and well-recognized hazard to highway/road/construction work zone employees. OSHA standards require such employees to wear high visibility garments in two specific circumstances: when they work as flagger (29 CFR 1926.201[1]) and when they are exposed to public vehicular traffic in the vicinity of excavations (29 CFR 1926.651[d]). However, other construction workers in highway/road construction work zones are also exposed to the danger of being struck by the vehicles operating near them. For such workers, the OSHA general duty clause applies (…*employment and a place of employment must be free from recognized hazards that are causing or are likely to cause death or serious physical harm to his employees*…) (OSHA 2009)

Conclusions

This case study reviews a serious double amputation injury resulting from a rearward-traveling bulldozer striking a backward-facing employee working on a landfill face as a waste spotter. Specific to this case study, it has been noted that a landfill face is a busy, noisy, hazardous work location with noisy work vehicles traveling in both the forward and reverse directions continuously. This case study outlined how each of the major contributing job activities was potentially defective and contributed to the resulting injury accident to include the following:

- Lack of a responsible individual on staff who is trained and knowledgeable in landfill safety issues.
- Defective and/or nonexistent safety procedures.
- Defective and/or nonexistent training.
- Defective and/or nonexistent worker communications guidelines.
- Defective and/or nonexistent approaches to enhance vehicle dynamic visibility.
- Defective and/or nonexistent approaches to enhance visibility of workers.
- Lack of recognition of the importance of the "see and be seen" visibility safety guidelines.

Landfill hazards and their countermeasures have long been noted and cited in the literature, and a typical succinct summary of landfill hazard countermeasures is given below.

"… it goes without saying that adopting safe procedures including the correct use of warning lights, mirrors and alarms on refuse collection vehicles together with the use of CCTV and radio communication on mechanical diggers on landfill sites which given the driver good all-round vision and the ability to communicate with those working at ground level have all had a dramatic impact upon reducing the number of accidents and injuries that occur." (Durham 2013)

The safe procedures noted above should include a properly designed hazard control program. This

comprehensive hazard control program should include the following more specific elements from Legler et al (2001):

1) Survey Hazards and Employees Affected

a. List the various hazard classes to which employees are subjected in the workplace. This can be done in general terms or can be listed by equipment type;

b. List the classifications of employees, who are affected by exposures to these hazards. Distinguish between those who will actually be authorized to work with machinery or processes with which the hazard is associated, those who are affected by the actions of authorized employees, and others whose duties might bring them into contact with the hazardous area or operation.

2) Catalog Preventive Measures

a. For each hazard, machine class, process or operation, list the preventative steps that must be taken to adequately control these hazards. Reference can be made to operator manuals which contain appropriate procedures, or a step-by-step process can be outlined;

b. Specify the types of special equipment or tools that must be used during the work process;

c. Specify who is responsible for ensuring that the procedures are followed, particularly if there is responsibility for a line employee over another.

3) Compile and Organize Control Policies and Procedures

a. State company identification and general safety policy regarding the hazard;

b. Organize preventive measures according to classes of machines, processes or operations and employees to be protected;

c. Specify policies for review of program performance, training of new or transferred employees, and recurrent training of authorized employees; delineate authority for supervision, training and review.

4) Designate Authorized Employees

a. Set out training and experience levels required for an employee job description to include authorization to control equipment of operations involving identified hazards;

b. If limited authority is given to certain employees, such as drivers or machine operators, so define;

c. Organize authorizations by classes of machines or hazards.

5) Conduct Training for Authorized and Affected Employees

a. Each job classification should receive complete training prior to being assigned to equipment service duties, or duties that involve potential hazards;

b. Other classes of employees should receive training in recognition of hazards as part of general orientation;

c. Employees should be provided with or have ready access to written procedures and/or equipment operating handbooks for reference while performing their job functions.

6) Document Training

a. List names, whether authorized, affected or recognition classification, and the dates of training. If employees work on different types of equipment or operations, documentation should cover training for each major category of equipment;

When employees are transferred or promoted, training records must document that training is updated.

7) Follow-Up Evaluation of Effectiveness (Periodic Review)

a. Review accident and incident reports for evidence of injuries or dangerous occurrences involving failure of the hazard control program;

b. Supervisory review of employee performance should cover proper use of energy isolation devices, locks and tags, and understanding of

company procedures.

8) Continuing Modifications and Revisions

a. Review new types of equipment or applications introduced since the last review to determine if new hazards exist and if established procedures are appropriate;

b. Document that procedures are changed to reflect inadequacies discovered during the review.

Recommendations

Typically, a single case study (such as the one described herein) being a sample of one, provides insufficient support from which guidance in the area of safety can be statistically extrapolated to the general landfill population at large. However, it is the author's belief that many of the safety issues uncovered during the analysis of this case study are potentially so fundamentally ingrained in the environment/machine/worker relationship found in landfill operations that general safety recommendations can be made, many of which can be applied to other landfills and/or other operations involving large construction and industrial vehicle operations. Furthermore, another landfill accident — this one involving a fatality on a landfill — was reported as occurring in 2002 (FACE 2015). In this fatality, it was the wheeled compactor traveling in reverse that struck a truck driver, whose back was turned toward the compactor, causing his death six days later.

The close parallels between the two accidents again support the concept that many of the fundamentally ingrained operations of landfill operations deserve and indeed require safety review and enhancement. Some of the specific recommendations listed below are adapted from FACE (2015).

Recommendation 1

Landfill owners should have in their employ a safety director and/or consultant who is responsible for the health and safety of all landfill employees. Given the nature and severity of the hazards existing on the landfill face, the safety director position should be a high level or staff position, preferably reporting to the president or CEO of the company.

Discussion

The safety director and/or consultant shall have overall responsibility of safety to include but not be limited to:

- Design and develop, implement, and enforce a comprehensive landfill health and safety program.
- Perform a hazard analysis for all employee tasks and design and implement countermeasures to these hazards.
- Design and develop a set of safety procedures which address landfill hazards, their control, and countermeasures.
- Create a traffic control plan for all landfill traffic, including that of the delivery truck drivers, that minimizes potential pedestrian-vehicle conflicts.
- Create a communication plan that provides for the means for communication between all individuals working near or on the landfill space, be they pedestrian workers, delivery truck drivers, or landfill equipment operators.
- To interface with the companies of the MSW delivery trucks to introduce them to the landfill hazard control plan and have them "buy-off" on their safety obligations as dictated on the plan.

Recommendation 2

The landfill safety and health plan should include a task description of each of the jobs that are present on the landfill. The task description should include hazard assessment, hazard countermeasures, vehicle and personnel movement analysis, and depictions of all potential landfill face traffic.

Discussion

The comprehensive landfill safety and health plan should include but not be limited to the following elements:

- Minimum time required for safety training and hazard countermeasure classroom training for each landfill task/job.
- Minimum physical training required for each landfill task/job.
- Requirement for periodic and regular formal review of safety issues germane to landfill safety.
- Organization chart depicting responsibilities and chain of command for all employees working the landfill.
- Due to its high hazard potential, an individual should be specifically trained and assigned as landfill face safety director.
- The specific responsibilities and place in the company organization chart of the landfill face safety director should be described and defined.
- A communications plan as to how the various vehicle operator and pedestrian workers on the landfill face can communicate.
- An accident emergency plan with a listing of the emergency medical health providers. Included in this

listing should be listed emergency ambulance or delivery services.

Recommendation 3

Pedestrian access must be limited to those needed to be on the face. Given the high hazard risk present on the landfill face, it is obvious that by minimizing the number and number of pedestrian workers and/or vehicular traffic would accordingly reduce the land face traffic hazards.

Discussion

Aside from the tracked and wheeled vehicles working the landfill face, there are, of course, the municipal solid waste (MSW) trucks delivering waste to the landfill site. On occasion, drivers of the MSW trucks will exit their trucks to open or close trailer doors to remove covers or to sweep out some waste stuck in the truck bed. This results in additional pedestrian workers on the landfill face, thereby increasing the hazard risk level. A number of approaches to reduce this hazard risk level would include the following:

- There should be only one waste spotter on the landfill face at any one time.
- All MSW truck drivers should open and secure the trailer door(s) prior to entering the discharge point at a working face.
- While at the landfill face discharge point, drivers should remain inside the truck cab while unloading.
- After unloading the waste, the truck should be pulled well away from the working face area to a designated, isolated cleaning or transfer area, where the truck can be cleaned and doors secured.

Recommendation 4

It is imperative that ongoing communication between the waste spotter and drivers of vehicles working the face be instituted and maintained.

Discussion

Aside from standard and agreed-upon hand signals between the face spotter and the vehicle operators, all workers and vehicle operators on the landfill face should be issued hand-held communicators (walkie-talkie) and maintain an open net with ongoing communication as to identify their location and direction and intended moves and/or actions.

Recommendation 5

All off highway construction vehicles working the landfill face must have rear-viewing closed-circuit TV (CCTV). Equipment manufacturers should be encouraged to test the effectiveness of forward and side view CCTV in conjunction with rear-viewing CCTV in reducing pedestrian injury in those equipment applications where pedestrians are required to regularly work in close proximity to construction equipment with blind zones.

Discussion

The size of the vehicles working the landfill face dictates that these vehicles (both wheeled and tracked) will have large areas or zones that are blind to the operator, even in a static mode. These blind zones are further exacerbated when considering the forward and reverse motion of the vehicles; the effects of the landfill face changing terrain; and the effects of a developing blind zone of a moving vehicle. Hence, readily available CCTV cameras should be mounted on the landfill face working vehicles to monitor blind zones at the rear of the vehicle.

Recommendation 6

Policies should be crafted and implemented by landfill management that require all landfill employees, visitors, and MSW truck drivers during delivery at the landfill site to wear high-visibility safety vests.

Discussion

Landfill management should require that all employees, visitors, and the MSW truck drivers during delivery on the landfill face wear high-visibility safety vests if it is absolutely necessary for them either to be present as a pedestrian or to exit their vehicles. Obviously, such a move would enhance worker visibility relative to the muted earth tone colors of standard work clothes.

For initial guidance in the proper choice of high-visibility work gear, ANSI/ISEA 107-2010 should be reviewed. Both OSHA and the U.S. Federal Highway Administration recognize the American National Standards Institute (ANSI) International Safety Equipment Association (ANSI/ISEA 107) standard as the industry consensus standard for the performance requirements of high visibility work gear. However, it cannot be overemphasized that ANSI standards are minimum consensus industrial standards. As such, they should be considered only as a starting point for determining guidelines for any specific safety evaluation and/or directives. Additionally, and more importantly, the waste spotter or any other pedestrian worker on the landfill face should wear a lighted safety vest, which are readily available, at all times when on the landfill face. Also, the waste spotter or any other pedestrian worker on the landfill space should wear a hard hat with a blinking light affixed. Such blinking lights are

readily available and typically used by bicycle riders to enhance their visible presence.

Recommendation 7

The landfill safety director should work with his regular MSW trucking company to develop and implement a common safety protocol and program.

Discussion

The landfill safety director should work and coordinate the landfill safety program with each of the landfill MSW trucking companies. The coordinated safety program should be formally accepted by each of the landfill regular trucking customers. This comprehensive safety and health program should be designed, developed, formally accepted, and enforced to minimize potential landfill hazards. The program should detail the approaches and methodology to train the MSW drivers to recognize and avoid hazardous work conditions and environments in a landfill. The truck drivers should be instructed by this document to identify hazardous situations and the chain of command on the landfill face. Standard landfill unloading and egress procedures should be defined and followed.

Bibliography

Bliss R. A compact guide to landfill operation – machinery, management and misconceptions. Waste Management World. Sept./Oct. 2006: 63-82.

CDC (http://blogs.cdc.gov/NIOSH-science-blog/2011/04/04/visibility/)

Connolly P, Delvin WA, Marcus KH. Design aspects for rear vision in motor vehicles. SAE Technical Paper 640652. New York: Society of Automotive Engineers: 1964.

Durham J. “Landfill and Waste Management Safety.” Updated March 22, 2013 (http://www.workplacesafety.co.uk/landfill-and-waste-management-safety.html). Retrieved August 13, 2015.

Fatality Assessment and Control Evaluation (FACE) Truck Driver Run Over by a Trash Compactor at Municipal Landfill – Case Report: 02NY007 (https://www.health.ny.gov/environmental/investigations/face//docs/02ny007.htm). Retrieved August 18, 2015.

ISO 5006-2006. Earth-moving machinery – operator’s field of view – test method and performance criteria. Geneva; International Organization for Standardization.

Josephs H. Forensic engineering review of forklift truck back-up visibility. Journal of the National Academy of Forensic Engineers. June 2003; 20(1).

Legler J, Malter D, Van Beek G, Eppes S. Manual of recommended safety practices. Washington DC; Environmental Industry Associations: March 28, 2001..

Occupational Safety and Health Administration (OSHA). High Visibility Garment Interpretation Letter, Aug. 5, 2009.

Pegula SG. 2004. Fatal occupational injuries at road construction sites. Monthly Labor Review. 12: 43-47.

The Facts About America’s Landfills. (http://www.postcom.org/eco/facts.about.landfills.htm). Retrieved August 13, 2015.

Walsh P, O’Leary P. Landfill equipment and operating procedures. Waste Age. 2002; 33 (9): 52-60.