BMC™: Baseline Report; Greenbook (Chapter)

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**BMCTM**

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Barrier Membrane Containment (BMCTM) is a high-density polyethylene membrane (HDPE) groundwater barrier and pass-through system, with applications ranging from plume control and containment to groundwater manipulation coupled with in-site treatment. BMCTM system can function as a permeable or impermeable reaction wall, a cut-off wall, interceptor trenches, a barrier with collection and/or monitoring system, and a pass-through in a funnel and gate configuration. BMCTM can be inspected with a down-hole video camera, producing a permanent VHS format tape, insuring the integrity of the wall and the interlocking joints. The joints are sealed with a “U”-packing elastomeric gasket to prevent the flow of fluids or gases.

KEY RESULTS

The installation of the BMCTM requires activities that would be classified as heavy construction and excavation; therefore, many of the associated safety and health issues are related to those activities. These, however, are important because installation of the BMCTM cannot be accomplished without these activities. The safety and health evaluation during the installation process revealed several areas of concern. Potential hazards that could cause injury, illness, and/or property damage, whether acute or chronic include:

- Slips/Trips/Falls
- Pinch Points
- Struck By/Caught Between Hazards
- Muscular/Back Injury
- Excavation Collapse
- Fall to Below Hazards
PART 2 - TECHNOLOGY DESCRIPTION

System Operation

BMCTM is a groundwater barrier and pass-through system with applications for groundwater containment and regulated pass-through. The photograph to the left shows a guide box being lowered into the ground.

Due to the patented guide box installation method, the system is capable of performing its function. This method allows for placement of piping and backfill into the clean void on both sides of the membrane. The guide box functions include providing stability of the trench walls and creating a sediment-free open area inside the box for membrane deployment and backfill. The standard designed trench width is 36 to 42 inches; however, BMCTM can be installed in a 24 inch trench or expanded to a size greater than the standard. The guide box width can easily be changed by widening the spreader bars and end gates. Width and depth of the trench depend on site-specific needs.

The HPDE is installed in sheets ranging from 8 to 300 feet long and 80 mils thick without a seam or joint. The thicker the material used, the shorter the distance between vertical joints. A dispenser containing the HPDE is inserted into the guide boxes and pulled along the length of the barrier wall. The membrane is held in place and centered or off-centered by insert beams placed inside the guide box. The vertical seams are interlocked using a patented seal. The seal consists of two ends that are heat fused to the ends of the panels prior to installation. Monitoring wells, pressure transducers, and in situ monitoring instruments can be installed on both sides of the barrier membrane. This will aid in providing data for meeting regulatory requirements as well as measuring barrier effectiveness. The photograph to the right shows the membrane in place in the ground after the guidebox has been removed. The pass-through provides a way for the groundwater to enter a treatment cell or reactor. The pass-through can be designed for site-specific requirements.

BMCTM systems operation does not pose any threats to workers' safety and health in and of itself. However, construction activities involved in the installation of the system pose the potential for safety and health hazards.
PART 3
HEALTH AND SAFETY EVALUATION

General Health and Safety Concerns

Personnel in the area where BMC™ is being installed need to be aware of the two main categories of safety and health issues: core issues, which are those based on current safety and health regulatory requirements; and best management practices, which are not based on current safety and health regulations but are key in preventing worker injury and illness on the job.

Safety and health issues of concern with the installation of BMC™ include:

Core issues:

- Slips/Trips/Falls - Jobsite conditions such as mud (caused by wet environmental conditions or wetting to keep the dust under control) and work materials lying on the ground caused extensive potential for slips, trips, and falls. Good jobsite housekeeping is essential.

- Struck By/Caught Between - Overhead lifting of materials and movement of heavy machinery was the source of these potential hazards. The use of warning devices on heavy equipment and standard operating procedures (SOP's) for prohibiting workers in certain areas needs to be evaluated.

- Excavation Collapse - Weather and soil conditions may cause the area of excavation to collapse. In addition, operator error may cause sloughing of the trench and must be considered. The need for support members and good ground control practices needs to be evaluated.

- Fall-to-Below - Trenching and excavation are an integral part of the use of this technology. A fall from ground level into an excavation may cause serious injury and property damage, and should by guarded against by the use of good ground control practices and training and the use of fall protection devices.

- Tripping and platform hazards - Extensive hazards existed from technology components on or about the work site. Workers working over top of an inserted box need to have a work platform to prevent fall-to-below hazards.

- Mechanical hazards - Hazards such as pinch points, struck by/caught between, and fall-from-above were present. Proper personal protective equipment (PPE) and SOP's can reduce the probability of these hazards.
• Overhead lifts - Serious injury and property damage may occur due to hazards associated with overhead lifts. Proper PPE and SOP's in accordance with safe construction practices can reduce the probability of these hazards.

• Dust - Dust monitoring needs to be considered. Other contaminants found in the soil may need to be monitored.

• Diesel fumes - The use of heavy equipment generates diesel fumes which may need to be monitored during installation activities.

• Noise - Equipment used during installation of the BMC™, usually more than one machine at a time, produced excessive noise levels. Personnel may need to be included in a hearing conservation program.

**Best Management Practices:**

• Ergonomics - Even though heavy equipment did most of the work, ergonomic concerns were still present. Activities such as pushing/pulling and hanging boxes, arm and whole body vibration, installing insert beams, and lifting objects were observed as potential causes of ergonomic problems. Anatomical devices such as back belts could be used for the ground workers to help correct posture while lifting. Training in proper lifting technique must accompany the use of PPE such as back belts.

• Moving vehicles - The opportunity for injury from moving vehicles was complicated by the small area of operation. Warning devices such as lights, horns, and bells need to be in operating order and utilized to prevent collision between equipment and workers.

• Heat stress - The workers were subjected to an increase in heat stress due to the utilization of different levels of PPE. During excessive heat, limitations of work (work/rest cycles) and medical surveillance must be used to ensure workers do not suffer heat related illnesses. Cold temperatures would generate corresponding concerns.

• Whole-body vibration - The operators were exposed to whole body vibration while operating heavy equipment. The equipment needs to be assessed for engineering controls for vibration. The use of anti-vibration cushions may also benefit the operators.

• Ground control - Ground control is a major safety and health concern of the jobsite. Recognizing fractures and sloughing of the trench is essential for maintaining the highest level of safety during operation. Weather conditions played a major role in fractures and sloughing of the trench during the human factors assessment, but recognizing these situations needs to be independent of the weather. In addition, heavy machinery may cause fracture to the trench. Workers need emphasis on ground control. This can be accomplished by
training and experience. Operators need to be aware of ground conditions and location of the trench to ensure maximum safety.

- Channel debris - The dirt which remained on the previously installed box which would not let the next box lock into place is termed 'channel debris.' Workers used a grade stick to remove the unwanted dirt. This presented a safety and health problem, because workers stood on top of the inserted box or on the edge of the trench while attempting to dislodge the dirt. Excavation collapse and fall-to-below were the main potential hazards. An engineering re-design of the box or a remote operation for removing the dirt would lessen the probability of a hazard.

- Level A Interface - Work in Level A (PPE) caused the workers the most problems. Problems included limited vision due to fogging of the suit faceshield and respirator lens, limited range of motion, suit malfunctions, limited mobilities, and heat stress. Workers cleared their faceshields by wiping them with towels and their respirator lenses by breathing deeply several times. (Taking several deep breaths is a commonly-used method to clear the moisture from the inside of a respirator mask.) Mobility increased as the workers became accustomed to the suit, but simple tasks such as reading the transit could not be performed. The hand liners on one of the suits were inside-out and had to be cut away so the worker could perform his work. Communication had to be accomplished by the use of hand signals. The only time workers could verbally communicate was when they were “shouting into one another’s ears.” Heat stress was a major problem. Breathing air was used up quicker due to an increase in respiratory rate, and the workers became extremely hot inside the suit. It was requested that the workers not over-exert themselves, take frequent breaks and be medically monitored.

- Level B Interface/Self Contained Breathing Apparatus (SCBA) - Work in Level B (PPE) caused some of the same problems Level A did, such as limited vision due to fogging of the respirator lens, and limited communication. The limited vision was remedied by taking a few deep breaths. Communication was done primarily by hand signals, although radios were used between the operator and ground crew.

- Level B Interface/Supplied Air Respirators with Escape (SARE) - Work in the SARE presented the same problems as the SCBA with the exception that mobility was more restricted because of a tether line. This also caused mobility problems for the operators because they had to avoid running over the lines. An additional problem with the SARE was the lack of a warning signal that the air supply was depleted. Even though the SARE is not inherent to this technology, the user needs to be aware of this and periodically monitor the air supply.

- Level C Interface - Work in Level C (PPE) had two limitations: vision, due to fogging of the respirator lens; and breathing, due to the use of a respirator. The vision problem was taken care of by taking deep breaths. Air purifying
respirators are twenty percent harder to draw air through than an SCBA; therefore, added stress is placed on the worker. Regular PPE was worn with respect to safe construction practices such as safety glasses, hard hat, and work gloves.

- Level D Interface - Work in Level D (PPE) gave the workers the least amount of restriction and discomfort. Proper PPE was worn such as safety glasses, hard hat, and work gloves. Steel toe boots were not worn and has been noted accordingly. No problems occurred during Level D that occurred in any other level of protection during the assessment.

- Good Construction Practices - Good construction practices need to be observed at all times, whether during BMC™ or during other activities: use of steel-toed boots, avoiding standing on the edge of a trench, and worker recognition of fall-to-below hazards, and the use of tag lines. During the assessment tag lines prevented unwanted movement of the wall sections while in the air and also aided the operator in interlocking with the existing wall section.

**INDUSTRIAL HYGIENE MONITORING**

Even though noise is not a direct concern with the BMC™, the noise generated by the use of heavy equipment for the installation may be loud enough to required the establishment of a hearing conservation program. The use of heavy equipment during the BMC™ installation created a concern for the noise levels being generated. Area noise measurements were taken in the area of the operator, ground crew, and assessment observers for the hoe, crane, and bobcat. Measurements taken for the backhoe showed a noise level of 83 dBA for the operator and 95 dBA for ground personnel. The crane showed levels of 85 dBA for the operator with the window open, 80 dBA with the window closed, and 85 dBA for ground personnel. During the crane measurements, a backhoe was being operated in the background. Measurements taken for the bobcat showed a noise level of 92 dBA for the operator and 95 dBA for ground personnel (located three feet from the bobcat). These area noise levels indicate a need for dosimetry to be conducted to determine an 8-hour time weighted average (TWA) for the operators and ground personnel and the potential for a hearing conservation program to be initiated. Feasible engineering controls, administrative controls, and personal protective equipment (PPE-hearing protection devices) need to be used to assure compliance with the OSHA noise standard.

Dust was not a factor during this assessment session because of wet weather conditions, therefore, air sampling for dust was not conducted. During dry conditions dust monitoring needs to be implemented. Site-specific air sampling plans will include monitoring for other contaminants in the soil at the site of installation. In addition, diesel fumes may need to be monitored.
HUMAN FACTORS INTERFACE

The human factors interface main area of concern was communication between operators and ground workers as well as activities of ground workers in various levels of personal protective equipment (PPE). Verbal interchange was the best method of communication, but was not always possible. Hand signals supplemented verbal communication. Difficulties in communication were dependent on the level of PPE being worn, with Level A having the most problems and Level D the fewest.

Work in Level A included problems such as:

- Limited Vision Due to Fog – Visibility was restored by the worker wiping his suit faceshield and breathing deeply a few times to clear the SCBA facemask.

- Limited Mobility - Mobility was improved as the workers became accustomed to the suit, but simple tasks such as reading the transit could not be performed.

- Suit Malfunctions – An example of a suit malfunction occurred during the assessment, when a suit’s hand liners were turned inside out and had to be cut away in order to perform the task.

- Limited Communication - Communication had to be done completely by hand signals. The only time workers could verbally communicate occurred when they were yelling in close proximity to each other.

- Heat Stress - Heat stress was a major problem. Breathing air was used up quicker due to an increase in respiratory rate and the workers became extremely hot inside the suit. It was requested the workers not over exert themselves, take frequent breaks, and be medically monitored.

Level B interface took place in SCBA and SARE respirators. Work in Level B produced some of the same problems as Level A, such as limited vision due to fogging of the respirator mask and limited communication. There was no warning of air depletion for the operators in the SARE. The user needs to be aware of this limitation and periodically monitor the air supply. Communication was accomplished primarily by hand signals, but radios were used between the operator and the ground workers. The main difference between the SCBA and SARE was presence of the tether lines. The ground crew’s and operator’s mobility was limited due to the tether lines on the ground crew’s SARE’s. Operators had to be conscious of the location of the tether lines to avoid them while performing operations such as backfilling.

Level C interface only had two limitations: poor vision due to fogging of the respirator lens, and increased respiratory effort due the use of air purifying respirators. The usual practice of simply taking a few deep breaths cleared the respirator lens. The second problem had no simple solution, since air purifying respirators are twenty percent harder to draw air through than an SCBA. As a result, added stress is placed on the worker.
Regular PPE was worn with respect to safe construction practices such as safety glasses, hard hat, and work gloves.

Level D interface gave the workers the least amount of discomfort and restricted mobility. Proper PPE was worn with respect to safe construction practices such as safety glasses, steel toed boots/shoes, hard hat, and work gloves. No problems occurred in Level D that occurred in any other level of protection during the assessment.

The purpose of the human factors interface assessment was to see how the workers and operators responded under changing work environments with different levels of PPE. This was documented accordingly. Evaluating these safety and health issues will result in recommendations for safe practices to be used during installation.

Ground workers and operators interfaced with machines during the entire assessment. Operators operated the machinery to the ground workers' specifications. During the same time, the operators had to be aware of the site-specific hazards such as location of ground workers and other machinery. Ground workers worked closely with the crane and its operator during the actual installation of the guide boxes. Communication was vital throughout the assessment, because the operators had to perform certain operations involving the heavy equipment while simultaneously working with the ground workers.

EMERGENCY RESPONSE/PREPAREDNESS

The use of BMC™ technology would not be applicable to emergency response due to the length of time required to install the components.

Emergency response/preparedness must be part of every hazardous waste site safety and health plan. In addition to credible site emergencies, site personnel must plan for credible emergencies in connection with BMC™ and its installation procedures.

All precautions used when responding to an emergency situation at the site will apply. Emergency trench rescue may be an issue and needs to be planned for in the site's Safety and Health Plan. According to 29 CFR 1926.651(g)(2), emergency equipment such as breathing apparatus, a safety harness and line, or basket stretcher shall be readily available for instances where trench rescue must take place under a hazardous atmosphere or one may reasonably be expected to develop during work in an excavation.

PART 4
TECHNOLOGY APPLICABILITY

From a safety and health point of view, the main concern with BMC™'s applicability is the level of PPE being used during installation. Different levels of PPE, as previously discussed, exhibit different concerns for the safety and health of workers. Visibility,
mobility, communication, and heat stress are the major areas of concern. When problems associated with these factors increased, workers had a difficult time performing activities associated with the installation of BMC™, such as getting a good seal when interlocking the barrier membrane.

An additional concern is the installation of BMC™ during inclement weather. Conditions such as sloughing of the trench can occur and need to be considered. Worker safety and equipment operation may be directly related to the weather. When inclement weather conditions arose during the human factors assessment, the Health and Safety Officer and BMC™ workers made the decision to proceed with the work because the weather was not severe enough to cause unsafe working conditions. This included ground conditions that would inhibit the operators from operating equipment safely and excavation collapse due to wet ground conditions. Environmental conditions must be taken into consideration and safety and health decisions made accordingly.

**PART 5**

**REGULATORY/POLICY ISSUES**

The site safety and health personnel where the BMC™ technology is being used need to be concerned with safety and health regulations applicable to the issues discussed above. Regulations that apply may be divided into four categories.

1. **Core requirements** are those regulations that would apply to any hazardous waste site, regardless of the type of job or technology being employed.

2. **Technology-specific requirements** are those regulations that apply due to the specific technology being used.

3. **Special requirements** are standards and policies that are specific to the technology itself and are required by reference in a regulation.

4. **Best management practices** are not required but are recommended by organizations such as the American National Standards Institute (ANSI), the National Institute of Occupational Safety and Health (NIOSH), Department of Energy (DOE), National Fire Protection Association (NFPA), etc.

**Core Requirements:**

- OSHA 29 CFR 1926.25 Housekeeping
- OSHA 29 CFR 1910.141 Sanitation
- OSHA 29 CFR 1926 Subpart Z Toxic and Hazardous Substances
- OSHA 29 CFR 1910 Subpart Z Toxic and Hazardous Substances
- OSHA 29 CFR 1926.59 Hazard Communication
- OSHA 29 CFR 1926.64 Process Safety Management of Highly Hazardous Chemicals
- OSHA 29 CFR 1926.65 Hazardous Waste Operations and Emergency Response
- OSHA 29 CFR 1910 Subpart K Medical and First Aid
- OSHA 29 CFR 1926.52 Occupational Noise Exposure
- OSHA 29 CFR 1926.103 Respiratory Protection
- OSHA 29 CFR 1926.28 Personal Protective Equipment
- OSHA 29 CFR 1910 Subpart I Personal Protective Equipment
- OSHA 29 CFR 1926 Subpart M Fall Protection
- OSHA 29 CFR 1926 Subpart P Trenching
- OSHA 29 CFR 1910.180 Crawler Locomotive and Truck Cranes
- OSHA 29 CFR 1926.550 Cranes
- OSHA 29 CFR 1910.184 Slings
- OSHA 29 CFR 1926.551 Slings
- OSHA 29 CFR 1910.133 Eye and Face Protection
- OSHA 29 CFR 1926.102 Eye and Face Protection
Best Management Requirements:

- ANSI S3.34 -1986 Guide for the Measurement and Evaluation of Human Exposure to Vibration Transmitted to the Hand

In addition to the above regulations and policies, it is imperative that all workers have appropriate and adequate training for the task and associated safety and health concerns. Training that would be required may be divided into four categories.

(1) Core training, which is required for anyone entering a hazardous waste site to perform work, regardless of the type of job or technologies being employed.

(2) Technology-specific training, that is specific to the technology and required by safety and health standards.

(3) Special training, which is specific to the technology to assure the worker is adequately trained for the task but is not necessarily required by safety and health standards.

(4) Best management practices, which although not mandated by health and safety standards, provide information and knowledge to the worker that will allow the worker to perform his/her job safely.

Core Training Requirements:

- HAZWOPER
- HAZCOM
- Site-specific Requirements

Technology-specific Training:

- Fall Protection
- Hearing Conservation
- Trenching and Excavation
- Personal Protective Equipment
Respirator Protection

Special Training:

- Ground Control Training/Recognizing Fractures
- Heavy Equipment Certification

Best Management Practices:

- Ergonomics (lifting, bending, pushing, pulling, use of anatomical devices, arm-hand vibration, whole-body vibration)
- CPR/First Aid/Blood borne Pathogens
- 10-Hour or 30-Hour Occupational Safety & Health Training Course in Construction Safety and Health
- Equipment Inspection Safety Program (Pre- and Post-Work)
- Heat Stress (learning to recognize signs and symptoms)
- Hand Signal Communication

PART 6
OPERATIONAL CONSIDERATIONS AND RECOMMENDATIONS

Recommendations made here for improved worker safety and health take into consideration the installation process of the wall. Any operations which took place during the installation process were observed and analyzed. The specific recommendations include:

- Hand protection should be utilized at all times. Many pinch points exist, and need to be safeguarded against. Work gloves are sufficient for protection against this hazard unless chemical contaminants are present. In that case gloves appropriate for the chemicals must also be used.

- Operations such as measuring the depth of the trench need to be conducted while standing away from the edge of the trench when possible. When it is not possible to stand away from the edge, fall protection must be utilized. Other operations such as interlocking walls and membranes need to be done as remotely as possible. This will guard against fall-to-below hazards as well as protection from potential pinch points.
It needs to be assured that jobsite materials such as tools and construction equipment are organized, and good housekeeping rules are followed. This will protect against slips/trips/falls and possible fall-to-below hazards.

- Heavy equipment needs to be equipped with proper warning lights and alarms. This will help prevent collision of machines as well as collision with ground workers. Installation of mirrors and seat belts will aid in the safety of the workers and operators.

- Use of fall protection is necessary to protect against fall-to-below hazards while working at the edge of the trench or above the wall. Barriers or guard rails can be utilized as well to achieve this goal. In addition, safety nets and human restraint systems can aid in protecting the workers from falling into the trench.

- Wearing the proper footwear such as steel toe boots with an adequate sole for traction will help avoid slipping hazards and crushing injuries to feet and toes. There should be a conscious effort by the workers to keep their boots clear of mud and other debris. This can guard against fall-to-below hazards as well as slips/trips/falls.

- The use of standardized hand signals should be incorporated as standard operating procedures. This is very important when communication can not be achieved by verbal means. Higher levels of PPE and noise from equipment operation require communication by hand signals.

- There was an extensive amount of lifting, pushing, and pulling of objects during installation of the wall. Ergonomics training on the use of anatomical devices and proper lifting techniques is essential to workers in preventing muscular and back injuries.

- Providing support members for the walls of the trench will guard against excavation collapse. This will also guard against fall-to-below hazards if a worker is standing near the edge of the trench when it collapses. This potential hazard will be site-specific, depending on the types of soil and weather conditions.

It should be noted that for the duration of the assessment the weather conditions consisted of periodic rain and relatively moderate temperatures. These conditions presented potential hazards that may not be present during other installation sessions. Air monitoring was not done for dust because the ground was mostly mud. If dry conditions are present, air monitoring is recommended. Heat stress was relatively moderate as well because of the temperatures. If high temperatures and humidity are present, this should be monitored extensively to ensure proper safety and health of the workers.
APPENDIX A
REFERENCES


Threshold Limit Values (TLV's) for Chemical Substances and Physical Agents and Biological Exposure Indices (BEI's), American Conference of Governmental Industrial Hygienists, 1995-1996.

ANSI 1986, Guide for the measurement and evaluation of human exposure to vibration transmitted to the hand, New York, NY: American National Standards Institute, ANSI S3.34.
