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Project Summary

Capture-and-Containment Systems for Hazardous Material Spills on Land

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Methods were investigated for sealing the surface of soils and thereby preventing the intrusion of spilled hazardous materials into the underlying ground water. Such techniques were sought to provide immediate, short-duration protection of spill sites (such as transportation accidents) until more permanent cleanup could be initiated. The goal was to develop a portable, self-contained, universal sealing system that could be operated by one person, retain the spilled materials for 24 hr, and create no hazards for the user or the environment.

The initial plan was to study sprayable sealants, but laboratory and pilot testing soon showed this approach to be impractical since leak-free coatings could not be achieved. Three classes of sealants were evaluated, including non-reactive, reactive, and repellent or surface-modifying coatings. Several different commercially available film-forming materials in each category were tested, but none of the resulting films were free of defects. Even polyurethane foams, which were the most encouraging, required a thicker coating than was practical. The effectiveness of all spray sealant systems also depended heavily on weather and soil conditions.

Tests with polyethylene waxes and films suggested that the latter would be a useful barrier for a wide spectrum of hazardous waste spills. Thus evolved the use of polyethylene tubes, which appeared to meet the project's requirements of capacity, portability, ease of deployment, and safe operation. Based on several iterations, a preliminary design was generated that consisted of a double-walled polyethylene bag or one-end-closed tube about 6 ft (1.8 m) in diameter and 20 ft (6 m) long. An apron at the open end can be positioned beneath the leak, and a smaller tube attached at the opposite end allows liquid to be drained or transferred to secondary containment. The package is less than 2 ft^3 (0.05 m^3) in volume and weighs less than 16 lb (7.5 kg). Such systems could easily be carried by bulk transporters and deployed by a single operator.

This Project Summary was developed by EPA's Municipal Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The incidence of accidental land spills of chemicals has increased with the growing use and transport of chemicals. Concern over such spills and the possible contamination of the soil and ultimately of ground water has been accompanied by only limited development of methods for preventing such contamination, particularly during the critical hours immediately after an incident. This project was undertaken to develop methods that would seal the surface of soils at a spill site and prevent the seepage of hazardous wastes into the groundwater. Application of such soil sealants immediately after a spill would confine the spilled material to the minimum area until more permanent containment and cleanup procedures could be implemented.

The design criteria outlined for such an emergency containment system are quite severe. Since site preparation would be minimal, the sealant must be suitable for different soils and terrains and must have resistance to punctures by rocks, twigs, and other debris. Since accidents frequently occur during inclement weather, any universal system must also be unaffected by rain, snow, cold, frozen ground, etc. Even under such conditions, the system should be capable of reducing soil penetration by 95% over a 1200-ft^2 (100 m^2) area under a 1-ft (30 cm) head of liquid for a 24-hr period (based on a hypothetical 10,000-gal (37900-L) spill)). Spilled material should not be able to seep around or under the edge of the sealed area. Such a system should not create any permanent environmental damage or be a danger to the operator. For prompt implementation, the system should be portable and self-contained so that it can either be carried by the transport vehicle or be brought to the site by the first emergency response unit. The system also should be deployable by one person, even under adverse weather conditions. Once the emergency is over, it should be possible to remove or deactivate the system. And last (if possible), the system should be fabricated from commercially available components.

The planned program called for using these criteria to evaluate various in-situ film-forming systems rather than manufactured films. Laboratory tests soon demonstrated that no candidate sealant would be able to assure an effective seal under the expected adverse field conditions and also meet the other criteria. Consequently, efforts were shifted to other methods based on the use of manufactured film barriers. Polyethylene was selected as the most economical, widely compatible, and widely available film for field purchase and installation as a pond liner.

From this barrier-film approach evolved the concept of a capture-and-containment-bag in which a spill, such as that from a leaking tankcar, could be collected and held until a temporary holding pond was prepared. The obvious extension of this idea was to use the bags instead of a holding pond if strength and capacity criteria could be met. The scope of the project was then redirected to evaluate various bag designs and constructions with this goal in mind.

Evaluation Program and Results

Spray Films

This program initially sought to evaluate film-forming sealant systems that could be field-applied at a spill to prevent leaking of materials into the soil in the vicinity of the spill. When pilot-scale testing made it clear that leak-free films were unlikely to be obtained under field conditions, this phase of the program was terminated. The following is an abbreviated description of the experimental work that led to that conclusion.

Candidate film-forming materials had been selected using criteria as follows:

- able to form a continuous film;
- sprayable by a portable system;
- able to form a protective skin in a relatively short time; and
- pose no serious threat to operator or environment.

Initial testing consisted of applying each material to a cardboard backing and observing the time for film formation and the nature of the film. Resistance to chemicals under a pressure head of 1 ft (30.5 cm) was then screened using the film-on-cardboard as the sample. Water, sulfuric acid, sodium hydroxide, trichloroethylene, methanol, naphtha, and methyl ethyl ketone were the screening chemicals used. This technique quickly reduced the number of promising candidates to the following five:

Polyco 2607,* an adhesive from the Borden Chemical Co.
Resin 115, a urethane from the Callery Chemical Co.
EP 65-86/88, a urethane from the Ashland Chemical Co.
Zonyl RP, a surfactant from the duPont Chemical Co.
Clindrol 100CG, a superamide from the Clintwood Chemical Co.

These candidate systems were subjected to more extensive laboratory evaluation in a specially designed spray chamber, which is described in the original report. Compatibility with and resistance to a wide range of organic and inorganic chemicals likely to be encountered in spill situations were then determined by exposing a 6-in. (15.2-cm) disk of the coated and cured asbestos paper to a liquid head of about 1 ft (30.5 cm) of the challenge chemical and observing the loss of head with time. This apparatus also is described in the original report. Selected results for the promising candidates appear in Table 1.

Some evaluations were also carried out after low temperature cures, as might be experienced in an actual spill situation. Though cure times were necessarily longer, the chemical resistances measured by the liquid transmissions were not significantly different. Results of these tests are included in Table 1.

*Mention of trade names or commercial products does not constitute endorsement or recommendation for use

Table 1. *Compatibility and Permeation Test Results on Asbestos*

Film Material	*Challenge Liquid*	*Liquid Transmission (ml/24 hr) at 20°-22°C**	*at 3°-5°C**
Borden's 2607	*Gasoline*	*13.4*	*15.5*
	Cresol	*1.3*	*1.8*
	Naphtha	*3.9*	*6.0*
	Water	—	*56.8*
	Sodium hydroxide	*3.4*	*66.2*
	Sulfuric acid	*2.1*	*37.1*
Clintwood's Clindrol 100CG	*Naphtha*	*2880-5760†*	
	Trichloroethylene	*5760-7200†*	
duPont's Zonyl RP	*Gasoline*	*5-7*	
	Cresol	*13*	—
	Naphtha	*9-225*	—
	Water	*19-380*	—
	Trichloroethylene	*8-140*	—
Callery's Resin 115	*Gasoline*	*0*	*5.9*
	Cresol	*11.3*	*2.3*
	Trichloroethylene	*2.4*	*4.8*
	Sodium hydroxide	*12.7*	*3.6*
	Sulfuric acid	*4.2*	*14.5*
Ashland's EP 65-86/88	*Gasoline*	*7.7*	*30.3*
	Cresol	*2.8*	*2.5*
	Trichloroethylene	*2.0*	—
	Naphtha	*3.5*	—
	Water	*6.9*	—
	Sodium hydroxide	*377*	*100*
	Sulfuric acid	*153*	*1*

**Cure temperatures*
†Breakthrough occurred within a few minutes.

Three types of commercially available equipment were considered for further testing of these systems: (1) hand-pump pressurized; (2) propellant pressurized; and (3) auxilliary-powered, pump pressurized. Laboratory tests indicated that 80 to 160 lb (35 to 70 kg) of material would be required to seal a containment area of 1200 ft^2 (100 m^2). To accomplish this in a reasonable time (15 to 30 min) would require spray equipment capable of dispensing 2.7 to 10.7 lb/min (1 to 5 kg/min) of chemical. Hand-pumped systems, while small enough to meet the project's criteria, would not be expected to give consistent pressures. Portable propellant pressurized systems, such as those used for the application of urethane foams (e.g. MSA's Rigi-Pak 180) came closest to meeting the criteria of light weight and adequate capacity. An auxiliary-power system could also be developed using an external power source estimated at about 2.75 kW or 2 hp, but there would be a serious weight penalty (275 to 350 lb) (125 to 160 kg) and a significant increase in cost.

Pilot scale tests on 10-ft^2 (1-m^2) areas using primarily the Callery urethane Resin 115, the MSA Rigi-Pak portable unit, and a Binks Model 18 spray gun demonstrated that operator experience was a major factor in obtaining uniform coverage at the desired 0.2 lb/ft^2 (0.1 g/cm^2) application rate. Surface and weather conditions, presence of debris, rocks, water, ice, etc. also appeared to play a role. Nevertheless, grassy soil (a relatively ideal substrate) could not be sealed even at a rate of 1.3 lb/ft^2 (6 kg/m^2), apparently because of a "shadow" effect during spraying. The sealant would have to be applied from all directions to obtain complete coverage and adequate sealing. In view of these considerations, this phase of the program was discontinued.

Bags

Experiments during the spray sealant study indicated that polyethylene film was an acceptable barrier film. From this conclusion evolved the concept of using a polyethylene tube to direct bulk transport leaks and spills of hazardous liquids to an emergency containment pond. And because there is a need for temporary storage of such chemicals until a pond can be prepared, a larger capacity tube or bag became the next logical configuration. This design, incorporating an apron at one end to capture the leak and a narrower tube at the opposite end for controlled discharge or transfer of the contained liquid (Figure 1), became the subject of further study.

Figure 1. Capture-and-containment device in use at a simulated site.

Such bags could temporarily replace polyethylene-lined containment ponds at the site of a spill if they were capable of retaining spilled material for a reasonable length of time and in significant volume. An added advantage would be a reduction in vapor problems that often accompany a spill.

The design finally developed was a polyethylene, pillow-shaped bag about 6 ft (1.8 m) wide and 20 ft (6 m) long, with an apron at one end and rope lines for use in positioning the apron capture section beneath the leak. A polyethylene tube approximately 4 in. (10 cm) in diameter and 30 ft (9 m) long at the opposite end of the bag served as an overflow or transfer tube.

Evaluation of several evolutionary versions of these bags consisted of introducing water (simulated spill material) at 5 gpm (20 L/min) into the apron of a bag, either fully deployed or rolled-up, and observing how well the bag unrolled or retained its shape and position on sloping ground and how much water could be contained before the bag failed. In this manner, it was demonstrated that the seals or seams of the bag and the junction with the overflow tube were the primary sites of failure when subjected to the internal pressure of liquid. Air pressure tests on small (6 in. x 9 in. (15.2 cm x 22.8 cm)), 4-mil-thick (100-μ) bags suggested that though the film and heat-sealed seams can be strong enough to withstand more than 30 in. (75 cm) of head pressure, quality control in mass fabrication was not adequate to assure a reliable seal for this application.

Two prototype bags constructed of clear (unreinforced), 4-mil-thick (100-μ) polyethylene tubes 6 ft (2 m) wide and heat-sealed at one end were found capable of collecting and holding several hundred gallons of water (simulated spill material) and withstanding a maximum head pressure of 24 in. (60.9 cm or 0.6 m). Flow into the bag and the development of the head pressure depended on the slope of the land on which the bag was deployed. The one failure occurred at a fold line in the bag at a head pressure of about 20 in. (50 cm).

Several full-scale versions were then constructed of fiber-reinforced polyethylene film to improve tear and puncture resistance in anticipated field situations. As these units were filled with water, leaks developed at or near the point where the transfer tube was attached, but not at the double-stitched seams covered with a polyethylene mastic tape. When the leaks were repaired and the bag was retested, some seepage was observed at the sewn seams, but only when the bag contained about 900 gal (3500 L) of water and was under a head of about 22 in. (55 cm). In a later test, a leak again developed at the junction of the bag and transfer tube. This bag, about 20 ft (6 m) long and 8 ft (2.5 m) wide (flat), weighed only 16 lb (7 kg) and was readily deployed in freezing conditions by a single operator.

Three manufacturers fabricated bags using both heat-sealed and sewn seams and fiber-reinforced film. These bags were tested under field conditions (Table 2).

To reduce the strain on the seams further, the next design consisted of double-walled bags, with the outer bag intended to supply support. Two units were purchased and tested. The first, manufactured by the Sheldahl Corp., consisted of an innner, 6-mil (150-μ) polyethylene bag and an outer bag of fiber-reinforced polyethylene. Though leakage was minor with this unit, even when filled to a maximum of 42 in. (105 cm) of liquid head, post-test examination showed that the inner bag had failed at some earlier time near the transfer tube in a manner typical of poorly heat-sealed seams.

The second double-walled bag, fabricated by Silco Industries, was a quarter-scale unit. The inner bag was 4-mil (100-μ) polyethylene with a continuous, heat-sealed seam. The outer bag was constructed of polyethylene mesh with a double-stitched seam. This double-walled bag successfully contained a water pressure head of 46.5 in. (115 cm). A full-scale version of similar construction used a fiber-reinforced polyethylene film outer bag (9-mil (226-μ) total thickness) with a double-stitched seam. Unfortunately, the outer bag was slightly larger than the inner bag and did not provide the expected support. The inner bag seam failed near the transfer tube connection after only 150 gal (600 L) of water had been introduced.

A field demonstration was carried out at the contractor's facilities using two prototype bags: a Silco double-walled bag and a single-ply Katz Co. bag. The simulated accident was a railroad tanker laid on its side with leakage around the top hatch (see Figure 1). Water was the simulated spill liquid at a leak rate of 5 gpm (20 L/min). The Silco bag had an inner bag of 6-mil (150-μ) polyethylene with continuous, heat-sealed seams and an outer bag of fiber-reinforced polyethyene film with double-sewn seams. The Katz Co. bag was constructed of a single-ply (9-mil (225-μ)), fiber-reinforced polyethylene film with seams heat-sealed by a proprietary process. The site had only a gentle slope, which limited both the potential head buildup and the total capacity of the bags. The tests did, however, demonstrate the ease with which the bags could be deployed and positioned to capture a spill, even by an operator in full safety gear, and the use of the bags in a modular or tandem scheme to increase capacity. Water (the simulated spill liquid) was easily transferred from the first, or capturing bag, to a second downhill bag without the operator having to re-enter the immediate area of the spill.

Table 2. *Tests on Fiber-Reinforced Bags*

Supplier	*Fabrication*	*Pressure (in.)* of H_2O*	*Observations*
Griffolyn Co.	*Heat-sealed*	*12*	*Failed near seams*
Griffolyn Co.	*Double-stitched and silicone taped*	*12*	*Small leaks at corners*
Griffolyn Co.	*Double-stitched and polyethylene taped*	*29.5*	*Filled to capacity; seams seeped*
Griffolyn Co.	*Heat-sealed with hot air*	*5*	*Zipper-like failure*
Silco Ind.	*Heat-sealed*	*5*	*Zipper-like failure*
Katz Bag Co.	*Extrusion process*	*48*	*No failure; 1/4 scale; some seepage*
Katz Bag Co.	*Mechanical seal at transfer tube*	*12*	*Leakage around seal*

** 1 in. = 2.5 cm.*

Conclusions

Polyethylene film is a suitable barrier film for the rapid fabrication of emergency holding ponds. Polyethylene film (6-mil (150-μ)) can contain water (simulated spill material) with more than a foot (30 cm) of liquid head over natural terrain containing rocks, twigs, and other debris. This material is readily and widely available, inexpensive, chemically resistant, and amenable to handling under the adverse weather conditions (except strong wind) frequently encountered at bulk transport spill sites.

Properly fabricated bags or tubes constructed from 6-mil (150-μ) polyethylene can capture and hold materials spilled during bulk transport accidents. These bags are attractive candidates for onboard spill containment equipment, since they can be deployed readily by a single operator immediately after an incident. The seams of such bags are the major weak point and the primary source of leaks. The best strength and resistance to leakage caused by internal pressure (liquid head) is obtained with a double-walled bag consisting of an inner bag with heat-sealed seams and an outer bag with sewn seams.

A prototype design includes an apron at one end of a 20-ft-long (6 m), 6-ft-wide (2 m) pillow-type bag. Through the manipulation of ropes, the apron can be positioned to capture leaking material. A transfer tube at the opposite end of the bag (about 4 to 6 in. (10-15 cm) in diameter and 30 ft (9 m) long) allows for transfer of the contained liquid to a second, downhill bag or to a prepared containment area without the operator having to re-enter the immediate area of the spill.

Such bags can contain more than 1000 gal (3785 L) of liquid on a reasonably sloping terrain, weigh less than 16 lb (7 kg), occupy a volume of less than 2 ft^3 (0.0566 m^3), and are readily deployable by a single person encumbered with full safety gear and facing adverse weather conditions. Such bags could probably be purchased in volume for $50 to $200.

The use of film-forming materials for onsite sealing of soils is not practical. The terrain frequently encountered is not likely to permit achievement of a continuous, leak-free film, even when using relatively high application rates. Adverse weather conditions would also contribute to an expected high frequency of failure for such sealant films.

More specific conclusions can be drawn for the three types of film-forming systems evaluated. Nonreactive sealants dispensed as solutions or dispersions are slow to form films under inclement weather conditions and could create fire or air-emission problems if used with an organic solvent. The films produced often have pinholes. Reactive sealant systems, though capable of forming films under adverse weather conditions, exhibit poor adhesion to the soil and form films with frequent holes or voids where vegetation or debris protrudes. Surface modifying chemicals such as repellents fail to provide a sealing effect when sprayed on soil, even under ideal conditions.

Recommendations

The capture-and-containment concept should be vigorously pursued as a first response to bulk transport spills. Polyethylene bags are attractive candidates for an onboard spill containment system for transport vehicles.

Though polyethylene film has adequate strength to contain such spills, particularly when fiber-reinforced, additional work is needed to fabricate bags with leak-free seams and junctions (at the transfer tube, for example).

Before manufacturers will undertake full-scale development of such units, evidence is needed of a potential market. Further design evolution should be explored with both manufacturers and spill response personnel.

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The complete report, entitled "Capture-and-Containment Systems for Hazardous Material Spills on Land," (Order No. PB 84-186 089; Cost: $11.50, subject to change) will be available only from:
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