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Implementation of Remedial Measures to Contain a Spill of PCBs

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SYNOPSIS: A large spill of Polychlorinated Biphenols (PCB’s) occurred at Federal Pioneer Limited’s Regina Plant in 1976. The City of Regina is underlain by a relatively shallow aquifer which supplies a significant proportion of its drinking water. A remedial measures plan was developed to contain this spill within the boundaries of the site and clean up any contamination which had spread to adjacent property. The remedial measures plan developed involved limiting or reversing the normal downward hydraulic gradient. The three principle measures introduced to accomplish this reversal included the construction of a cutoff wall around the site, installation of a thick surface seal over the entire surface and active dewatering. The performance of these measures was monitored by an extensive network of piezometers and sampling wells. Monitoring over the past seven years has produced no evidence of further downward migration of PCB’s.

INTRODUCTION

The development of remedial measures to contain and control the spread of hazardous waste is one of the most challenging tasks in waste management. Many of these wastes are chemically active and present a threat to uncontaminated groundwater and must be contained for considerable lengths of time. This paper presents a case history of the development, installation, monitoring and analysis of remedial measures designed to control a spill of liquid PCB. It describes the background of the spill and development of the remedial measures plan. The installation of the remedial measures and problems encountered during the installation are also presented. This paper also describes the monitoring system set up to measure the effectiveness of the system and presents an analysis of monitoring results over the past seven years. This analysis shows that the system has been effective in preventing further downward migration of PCB’s and should remain effective as long as the remedial measures are adequately maintained.

BACKGROUND

In 1976, Canada’s first major known spill of PCB’s occurred at Federal Pioneer Limited’s Regina Plant. This plant used a non-destructive oil containing 70 percent PCB’s and 30 percent tri- and tetra-chlorobenzene (TCB’s) in the manufacture of transformers. The oil was stored in an outside tank and pumped to the plant through an underground line. The exact date this line ruptured is not known, and the total quantity of PCB’s released is also not known. However, a review carried out by the National Research Council of Canada (NRCC, 1980) estimated that up to 21,000 litres of oil was involved. At the time of the spill little was known about the health hazards of PCB’s or their threat to the environment. Even less was known about how to effectively contain such a spill. The manufacturer responded to the spill by drilling some shallow holes to pump off free oil, and had a thin asphalt seal placed over the PCB saturated soil.

In 1977 the Canadian Government prohibited the use of PCB’s for most applications. This increased awareness of the potential problems associated with PCB’s and in 1978 public concern was expressed over the security of the city of Regina’s drinking water. The reason for this concern was the presence of an important aquifer under the site which supplies approximately one-third of the city’s drinking water. These concerns eventually lead to the formation of an ad hoc panel of scientist under the umbrella of the National Research Council of Canada. This panel was requested to evaluate information on the nature and consequences of the spill, and prepare a public report. The report (NRCC,1980) identified the major areas of contamination and recommended that all of the contaminated soil under the plant be eventually removed and deposited in a hazardous waste facility.

The major areas and the depths of contamination identified in the NRCC study are shown in Figure 1. The manufacturing plant is located on a lot approximately 105 m wide and 190 m long. Old concrete pads at the rear of the lot mark the location of a previous plant which burned in 1974. The natural slope of the site changes near the rear of the plant, with water draining to the north and south. The location of heaviest concentrations of PCB’s were found at the north-east corner of the plant near the location of the buried underground line. PCB’s migrated out from this location to the west along an underground power line trench, south along the east limit of the building and east to an old transformer oil sump. Other areas of contamination were found near the railroad tracks where the oil was unloaded. The high costs associated with the removal of the contaminated soil and the lack of a suitable facility in the Province of Saskatchewan to deposit such waste forced the company to look for more economically acceptable alternatives. Thus, in 1980 a team of waste management and environmental specialists headed by Ground Engineering Ltd. of Regina was engaged to develop a set of remedial measures to secure the site and enable the company
Christiansen (1979) carried out an investigation to determine the geology and stratigraphy underlying the site. This information is presented in Figure 2. It shows a north-south cross section through the site. The surface of the site is covered with approximately 1 m of fill. Underlying this fill is a weathered clay referred to as Regina Clay. This highly plastic clay was formed in a large glacial lake during the recession of the last ice age. Its depth varies from 7.3 to 8 m. under the site. Prolonged periods of drying have resulted in severe desiccation of this clay, significantly increasing its permeability. The clay is underlain by 3 to 7 m of silt. Christiansen (1979) found some indications of weathering in the upper portion of this silt deposit. The silt is underlain by 1 to 5 m of soft till, which is underlain in turn by 5 to 6 m of hard till. Underlying the till is a deposit consisting of from 16 to 22 m of interglacial silts and sands. The Regina Aquifer is located in this zone, approximately 35 m below the surface of the site.

An east west cross section through the zone of deepest contamination is shown in Figure 3. This figure conceptual illustrates how the cutoff wall, surface seal and dewatering combined to enhance the containment strategy.

The remedial measures plan involved excavation of contaminated soil on the fringe and outside the boundaries of the site. Soil containing more than 50 ppm PCB's was excavated in this process. The contaminated soil was transported to an interim storage facility established on the east side of the plant. It was intended that this facility would hold the contaminated soil until a permanent facility was constructed for such purposes.

The effectiveness of these measures was monitored with a network of piezometers spread over the site. The volume of water collected in the sumps...
was recorded and its PCB concentration checked periodically. In addition, the movement of the deepest contamination was monitored with a deep hole drilling and sampling program.

IMPLEMENTATION OF REMEDIAL MEASURES

On September 15, 1980 Saskatchewan Environment formally gave approval to proceed with the remedial measures plan. The first step in implementing the remedial measures involved further drilling and sampling to determine the exact extent of the contamination off site. At the time this was proceeding contract documents were drawn up and discussions commenced with various contractors. The principle areas of work involved excavation of the contaminated soil, construction of the cutoff wall, placement of the surface seal, and installation of the dewatering and monitoring network. Negotiations were also commenced with government agencies responsible for workers health and safety, to ensure smooth implementation of the remedial measures.

Excavation of Contaminated Soil From Off Site

The primary locations of excavation of contaminated soil are shown in Figure 4. The soil excavated from these areas was transported to the Interim Storage Facility. The initial estimation of the quantity of contaminated soil of the site was 300 m³. However, this increased substantially as the excavation proceeded. It was estimated that the contamination in these areas would vary in depth from 0.3 to 3 m. The contractor was directed to excavate the contaminated soil by advancing excavation equipment towards areas of greatest concentration, without backing equipment over contaminated soil and back on to uncontaminated soil. The contractor was instructed to take precautions to ensure that contaminated soil did not spill while being transported to the Interim Storage Facility. Water found in the excavation as a result of rainfall or seepage was treated as contaminated, and pumped into special containers. These containers were numbered and stored for later treatment or disposal.

Area "A" was located on the western boundary of the site near a electrical power facility serving the plant. The PCB's apparently migrated along the north wall of the plant and over to this facility through an underground concrete service conduit. Excavation in this area was delayed until the electrical power facility was moved. Area "B" was located outside an old Askarel sump on the eastern boundary of the site. This unlined sump contained high levels of PCB's and some had migrated down slope to the east.

Area "C" was located near the rail oil unloading facility in the north-east corner of the site. The depth of contamination in this area was initially considered shallow. However, soil sampling and testing following excavation continued to show high levels of PCB's. Figure 5 shows a hydraulic excavator attempting to reach the lowest levels of contamination, near the base of the weathered clay. In addition to these areas some minor contamination at the south end of the site was also excavated for storage in the Interim Storage Facility. Following excavation these areas were backfilled and compacted with uncontaminated soil.

Interim Storage Facility

The Interim Storage Facility was designed to receive contaminated soil from off the site. It was constructed in the weathered clay on the east side of the plant. This area was flooded with PCB's during and shortly after the pipe line break. Thus, the PCB concentrations in these soils were carefully monitored during excavation. Uncontaminated soil was separated from contaminated soil for future use, and contaminated soil was placed back in the completed facility. The depth of the facility varied from approximately 1 m at the south end to 2 m at the north end. The facility covered an area approximately 12 m wide by 37 m long. This was later increased to approximately 14 m by 64 m for the above ground level storage. The
base and sides of the excavation were lined with compacted 5 percent lime-modified clay. Lime was used to inhibit the swelling characteristics of the highly plastic clay. The base of the facility consisted of two 150 mm lifts of lime modified clay compacted to 98 percent of standard Proctor density. Following compaction the lime modified clay was covered with a liquid asphalt seal coat.

Special provisions were made for the placement of the contaminated soil in the Interim Storage Facility. This soil was placed in a loose layer of approximately 150 mm in thickness. The contaminated soil was mixed with 2 percent lime by weight and compacted to 95 percent of standard Proctor density. Figure 6 shows the contaminated soil placement and compaction operation in progress. The final step in the construction of this facility involved the installation of a surface seal. This seal consisted of 300 mm of lime modified contaminated clay, covered with a 150 mm hot mix sand-asphalt base course.

Fig. 6 Placement of Soil in Interim Storage Facility

Washdown Facility

A temporary washdown facility was constructed immediately north of the Interim Storage Facility. This shallow washdown area consisted of 200 mm of 95 percent standard Proctor density compacted clay. A medium curing liquid asphalt was sprayed over the compacted clay to further improve the seal. The final layer of protection consisted of a polyethylene geomembrane.

This facility proved difficult to maintain and a more permanent installation was constructed. This facility was established over a concrete sump located at the rear of the plant (Figure 7). This sump was turned into a washdown facility by installing a heavy steel channel iron grate capable of supporting large construction equipment.

All equipment used to excavate or handle contaminated soil was washed in these facilities. Washing consisted of alternately spraying the equipment with acetone and hexane. These facilities were also used to decontaminate drilling and sampling equipment.

Fig. 7 Decontamination of Construction Equipment at Washdown Facility.

Installation of Cutoff Wall

A key element of the containment strategy was the installation of a cutoff wall around the site. The location of this cutoff wall is shown in Figure 4. The length of the wall was approximately 550 m, and extended down to a depth of 10.5 m. A vibrated beam cutoff wall was chosen because it can be used to install a wall through potentially contaminated soil without excavating additional soil. This reduced the volume of soil requiring storage in the Interim Storage Facility and decreased the risk of further contamination.

The thin cutoff wall was constructed using a vibrating beam having a web depth of 500 to 825 mm, and a flange width of 250 to 375 mm. An attempt was made to ensure that the beam was plumb to within plus or minus 1 percent. A minimum overlap of 1 m of wall was constructed at all changes in direction.

Figure 8 shows the installation of the cutoff wall. The wall was constructed from a mixture of sodium bentonite, fly ash and soda ash in water. Special attention was given to the seal between the cutoff wall and the surface seal.

Fig. 8 Installation of Vibrated Beam Cutoff Wall
Surface Seal

The installation of the surface seal was a critical element in the overall containment strategy. A significant effort was made to minimize infiltration. This involved the construction of a continuous seal capable of draining precipitation from the site. However, the site contained a number of areas requiring special attention. Some of these areas consisted of old cracked and weathered concrete from the previous plant. The concrete at the rear of the plant was also at the same elevation as the floor of the plant and restricted positive drainage off the site. Manholes leading to abandoned sewer lines, space adjacent railway tracks, transformer enclosures and other such facilities also presented problems. To accommodate these variations, the nature, type and quality of surface seal varied considerably from location to location. In addition special measures had to be taken to ensure that continuity existed between the different seals.

In unsurfaced areas, the general approach used was to excavate the subgrade, mix this soil with lime and compact. The thickness of this lime modified clay varied up to 450 mm. Prior to compaction the soil was pulverized and dry lime was added at a rate of 5 percent by weight of soil. The lime was mixed with the soil with a rotary mixer and water added in the field.

The lime modified clay was covered and brought to grade with an asphalt seal. This seal consisted of a hot sand-asphalt base mix overlain by a hot asphalt concrete surface course. The thickness of these layers varied from 0 up to 50 mm for surface course material and up to 100 mm for base.

The old concrete at the rear of the plant was handled in different ways. The large concrete pad at the rear of the plant was covered with asphalt concrete. The old concrete pad west of the railroad was covered with a new layer of concrete. The new lift of concrete was placed back from the edge of the existing concret to improve its seal with the adjacent asphalt overlay seal. Concrete was required to provide the plant with structures capable of supporting heavy transformers. For this reason some additional concrete was poured in area outside the north-east corner of the plant and at the north east corner of the site.

Installation of Dewatering and Monitoring Equipment

The location of the shallow dewatering sumps used to dewater the fill are shown in Figure 9a. This figure also shows the location of the storage tank used to hold the water removed from the sumps. In addition, a purge well was located at the center of the PCB area next to the location of the pipe line break. A total of 13 sumps were installed. Three of these sumps are located inside the plant. Sump 6 is the concrete lined sump used to decontaminate excavation equipment. Sump 8 is an old Askarel sump.

The location of the most frequently recorded piezometers is shown in Figure 9b. A total of 73 piezometers have been installed on this site. Most of these piezometers were read on a weekly basis since completion of the remedial measures.

PRELIMINARY EVALUATION OF REMEDIAL MEASURES

The remedial measures were completed in the summer of 1981, when monitoring was commenced. The sumps were dewatered when sufficient water was available to enable them to be pumped. The piezometers were read weekly, except during the winter when the water was frozen. The initial dewatering rates were surprisingly high. During the first year sumps dewatering the perched water table in the fill were quite active, producing approximately 20,000 liters of water. In 1982, the first full year of operation, their yield increased to approximately 110,000 liters. In 1983 this value dropped somewhat to near 90,000 liters. However, in 1983 it increased again to near 125,000 liters, when it was recognized that the majority of the water being removed was due to infiltration of precipitation. This conclusion was based on the close comparison between dewatering and precipitation.

A review of the initial remedial measures found a number of potential sources of infiltration. The first was the general lack of continuity and adequate grade at the rear of the site. The second was the presence of open or poorly sealed areas along the railway tracks and around a large complex of transformers adjacent the outside north wall of the plant. In addition, considerable water was being discharged onto the rear of the site from the roof of the plant itself. Based on this review a second phase of remedial measures was initiated.
re-directing runoff from the plant roof.

The majority of this work was completed in 1984. Only the addition of flashing around the building adjacent to its contact with the asphalt pavement was left until 1985 for installation.

PERFORMANCE EVALUATION OF THE REMEDIAL MEASURES

The performance of the remedial measures has been monitored over the past seven years. The goal of the remedial measures was to strictly limit or reverse the normal downward hydraulic gradient under the site. If successful the level of dewatering of the fill should drop significantly. A second measure of the performance is given by the variation in water levels of the piezometers. However, these levels are also influenced by lateral movement of water under the site and reflect general trends rather than precise determinations. A third measure of the performance is given by the volume of PCB's removed from the purge well and the location and levels of contamination reported in the deep hole drilling monitoring in the vicinity of the purge well.

Piezometers

A typical piezometer profile over the past six years is presented in Figure 10. This piezometer is located inside the north wall of the plant. The base of the piezometer is located in sand lenses in the silt. This piezometer was flooded in 1982 to measure its response. Since that time the water level has been dropping yearly to its 1981 value of 570.3 m. This and some of the other deep piezometers have shown a tendency to drop slightly during summer as a result of the dewatering, and increase in elevation during the winter.

![Piezometer Profile](image)

Fig. 10 Variation in Water Elevation with Time for Deep Piezometer No. 32

Sump Dewatering

The volume of water removed from the sumps has shown a considerable decrease since the installation of the remedial measures. Figure 11 shows the cumulative yield from these sumps for the past seven years. The cumulative yield values start in January and end in December as the 12th month. The second phase of the remedial measures was carried out in 1984. The volume of water extracted from the sumps has fallen every year since, to near one-third of its 1984 level by 1986. The 1987 values indicate further improvement.

![Cumulative Yield From Dewatering Sumps](image)

Fig. 11 Cumulative Yield From Dewatering Sumps From 1981 to 1987.

Another illustration of the improvement in the surface seal is shown in Figure 12. It presents a comparison of the ratio of sump yield in litres to precipitation in mm. The figure clearly illustrates the connection between precipitation and infiltration. It also demonstrates the effectiveness of the 1984 remedial measures in lowering infiltration through the surface seal.

![Variation in Yield Versus Precipitation](image)

Fig. 12 Variation in Yield Versus Precipitation

Figures 11 and 12 clearly show that further improvements in restricting inflow are possible. However, most of the obvious sources of infiltration were dealt with in the 1984 improvements. The one source of possible infiltration causing some concern and not dealt with at that time was the quality of the seal over the Interim Storage Facility. Sump 8 located a short distance north of this facility has consistently been the leading source of water. In addition the height and geometry of this facility made placement and compaction of the asphalt surface seal very difficult. As a result cracks of up to 100 mm opened every spring along the sides and top of this facility. These cracks were sealed with various asphaltic compounds on a regular basis. However, the cracks still re-opened. A number of attempts were made to check the possible influence of this facility by placing
die in the crack. Unfortunately no trace of the die was found at any of the sumps.

A further analysis of the present situation can be made by examining the cumulative yield versus precipitation relationships for sumps located near a far away from the Interim Storage Facility (Figure 13). This figure shows that the ratio of yield to precipitation is considerably higher for the sumps located near the Interim Storage Facility.

The information obtained from the purge well and deep drilling and sampling program in the vicinity of the purge well has found some free PCB’s in the clay. It also found some evidence of lateral migration in the clay above the silt. However, it showed no evidence of any downward migration of PCB’s.

![Graph showing yield versus precipitation ratios for sumps located near and far away from the Interim Storage Facility.](image)

**Fig. 13 Comparison of Yield Versus Precipitation Ratios for Sumps Located Near and Far Away From The Interim Storage Facility**

**CONCLUSION**

Information obtained from the ongoing monitoring and surveillance program has shown that the remedial measures and containment strategy developed have been effective. No evidence has been found of further downward migration of PCB’s. The monitoring data also shows that water entering the fill has been considerably reduced, thus minimizing the potential for downward movement of PCB’s. The piezometers have also shown evidence of the effectiveness of the dewatering program.

While these measures have been effective to date, there is also evidence that the remedial measures must be adequately maintained to ensure a continued successful performance of the containment system. For this reason it is essential that a permanent monitoring and surveillance system be set up and maintained for such system.

A review of the measures used and effort expended on this project to completely seal the surface and dewater the fill demonstrates the difficulties of such a task. It also demonstrates the increased effort and attention to detail required to move towards a "perfect" surface seal.

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