

# Dry Cleaners, Perchloroethene and Glacial Aquifers — Lessons Learned on Long Island, New York

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## Abstract

The commercial dry cleaning industry has existed from the mid 1800's to the present. This paper presents a history of dry cleaning technology and the waste streams generated by these processes. Historically, numerous dry cleaning facilities have experienced releases of perchloroethene. Based on the author's work at numerous dry cleaning facilities located on Long Island, New York, typical perchloroethene releases in a glacial aquifer setting are presented. Three categories of perchloroethene fate and transport are described. A summary of available remediation technologies is also included.

## Introduction

With the advent and enforcement of regulatory programs such as the U.S. EPA's Underground Injection Control, (UIC) program, State & Federal Superfund programs and County Public Health Ordinance; the Dry Cleaning Industry has been the subject of much attention from the regulators administering these programs. The following paper presents an overview of the history of the dry cleaning industry and of some of the author's experiences at Dry Cleaners facilities in the Long Island, New York area.

## Hydrogeology of Long Island

The majority of Long Island is covered by the highly permeable sands and gravels of the Pleistocene Upper Glacial Formation. This formation varies in thickness and is generally not used for water supply purposes except for areas in eastern Suffolk County. A generalized geologic cross-section of Long Island, New York is included as Figure 1. The Upper Glacial Formation unconformably overlies the Cretaceous Magothy Formation, the principal water-supply aquifer for most of Nassau and Suffolk Counties with many wells on the order of 400 to 600 ft in depth. The upper portion of the Magothy Formation is generally of low to moderate permeability and overlies highly permeable sands and gravels in the basal section of this geologic unit. The Magothy Formation is, in turn, underlain by the Cretaceous Raritan Formation. The Raritan Formation is composed of the upper Raritan Clay, a regional confining layer, that overlies the more permeable Lloyd Sand. The Lloyd Sand was deposited directly upon Precambrian crystalline bedrock (McClymonds and Franke, 1972).

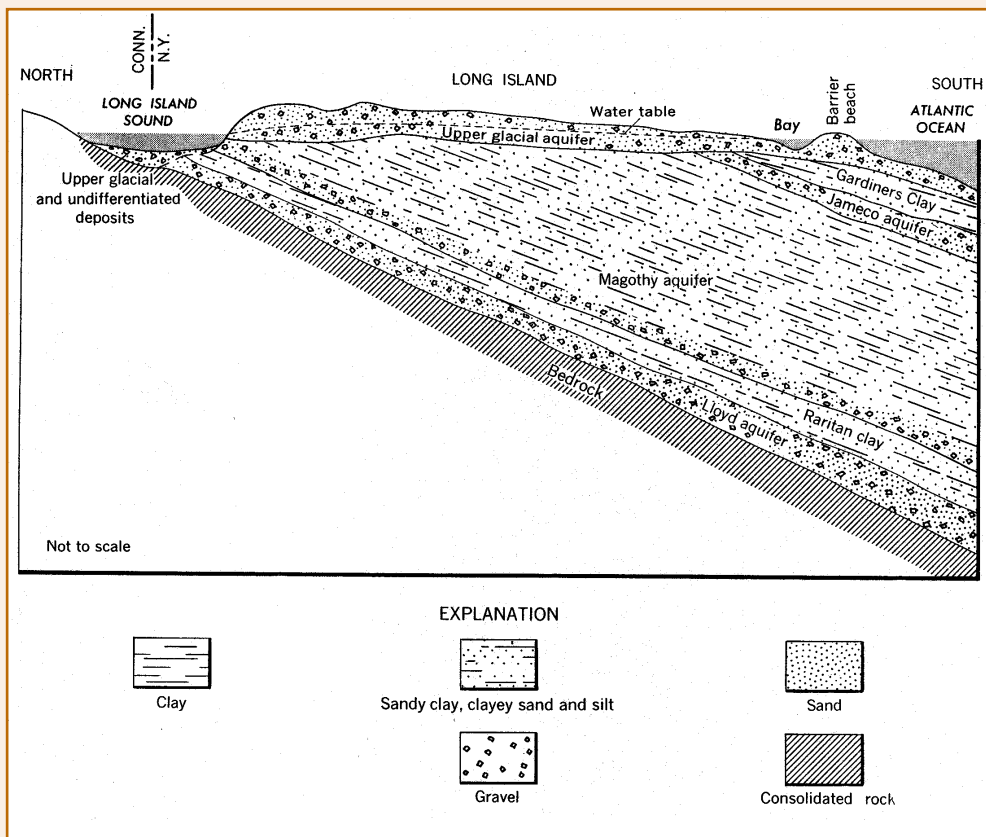


Figure 1. Generalized Geologic Cross-Section of Long Island, New York. Source: (McClymonds and Franke, 1972).

## The History of Dry Cleaning Technology

The first commercial dry cleaning plant was probably opened in Paris, France in 1845 (the Encyclopedia Americana International Edition, 2000). This technology quickly spread throughout Europe. The products initially used to “dry” clean clothing were hydrocarbon-based solvents and included benzene, benzol, naphtha, and gasoline. Dry cleaning became a commercial enterprise in America during the 1900s. During the 1920’s Stoddard solvent – with a flash point of 100 degrees F – was developed for use in the cleaning industry. Although these solvents were acceptable as cleaning fluids, their flammable nature presented a hazard to the operator of the equipment. As the technology of dry cleaning advanced, the use of chlorinated solvents became popular during the 1930s. This was due in part to the cleaning properties of these products as well as their non-flammable composition. Carbon tetrachloride was first introduced during the 1930s as a dry cleaning solvent (William Seltz, personal commun., Sept., 2000). This was later replaced by trichloroethene and eventually (in the late 1930s to early 1940s) by perchloroethene (PCE).

Perchloroethene has remained as the solvent of choice for most American dry cleaning operations. It has many advantages over some of its earlier predecessors, such as:

- High flash point (non-flammable),
- Excellent cleaning characteristics, and,
- Reduced fading of dyed fabrics.

The first of the modern dry cleaning machines introduced in the 1930s are known as “First Generation” machines and actually consisted of two machines – one for washing and one for drying. Also known as transfer machines, these units allowed for the generation of vapors within the plant as the cloths were transferred while still wet with solvent from the cleaning machine to the drying machine.

The next improvement in the technology of dry cleaning occurred in the 1950s and consisted of combining the cleaning process and the drying process into one unit. These “Second Generation” machines – also known as dry-to-dry machines – had the advantage of allowing the clothes to be washed and dried in one process.

In the 1970s, “Third Generation” dry cleaning equipment became available that included a refrigeration unit. This addition greatly decreased the amount of perchloroethene vapors emitted during the operation of the equipment.

“Fourth Generation” dry cleaning units became available in the early 1990s. These included a fan within the machine that pulls air into the cleaning drum when the door is opened. The captured air is passed through a carbon unit to reduce emissions of perchloroethene. Also common to the fourth generation equipment is the addition of a spill pan below the machine to contain any perchloroethene than may accidentally be released from the unit.

Most recently, “Fifth Generation” dry cleaning equipment has been introduced in the late 1990s. The fifth generation equipment includes a lock on the door to the machine. Sensors monitor the concentration of perchloroethene vapors in the drum and will not allow the door to open until the level is acceptable.

## Waste Streams Produced by Dry Cleaning Facilities

There are two predominant and separate waste streams generated by dry cleaning facilities that pose potential sources of soil and ground water contamination.

**Distillation sludge** – Virtually all modern dry cleaning machines include an internal distillation unit to clean used perchloroethene. The sludge produced from this process is commonly referred to as “still bottoms” and is the major waste product produced by the cleaning process. This perchloroethene-saturated material is an F-listed hazardous waste in accordance with U.S. EPA regulations and is typically black in color. Most operators empty the chamber that holds the still bottoms on a weekly to bi-weekly basis and will generate less than 27 kilograms of waste per month for disposal by a permitted waste hauler. This typically qualifies dry cleaners as conditionally exempt small quantity generators of hazardous waste in conformance with the Resource Conservation and Recovery Act (RCRA).

**Separator water** – During the process of cleaning, moisture from the clothes is captured by a separator and collected in a container situated along side of the unit. This water contains dissolved perchloroethene at or near its saturation concentration. Separator water is typically containerized and disposed of by a permitted hauler or treated on-site using one of numerous commercially available treatment units. This water should not be discharged to municipal sewage treatment plant or to on-site cesspools.

## Typical Releases Observed at Dry Cleaning Facilities

A description of a typical solvent release at a dry cleaning facility is difficult to describe as the circumstances leading up to releases are either unknown or not revealed. Often the releases have occurred years in the past and the operator during that period of time is unavailable. The sources of the release can be either unintentional (such as leaky equipment) or intentional (such as discharges to on-site drainage structures). The following are three general categories of releases.

1. Historically, discharges of separator water may have occurred either to on-site cesspools, exterior storm drains, basement floor drains, or to the ground surface. Separator water is water that is saturated with perchloroethene, but does not contain non-aqueous phase liquids (NAPL).
2. Another form of past releases was on-site disposal of still bottoms. These black sludge materials have been found in on-site storm drains and in the soil below basements of dry cleaners.
3. The third, and perhaps the most difficult category of release to remediate, is a bulk discharge of perchloroethene. This type of release can occur either as a leak from the cleaning equipment, on-site storage tanks or from transfer pipes.

## Fate and Transport of Perchloroethene in a Glacial Aquifer System

The fate and transport of perchloroethene in the subsurface is closely related to the amount and nature of the release. Several different scenarios are presented below.

One very common occurrence is a release perchloroethene saturated water to a floor drain or storm drain. An illustra-

tion of this type of release is in Figure 2. This results in contamination of the subsurface soil. If there is a sufficient distance between the drainage structure and the water table, the underlying ground water may remain unaffected or only be slightly impacted by the release. This type of release is common in cleaning plants that are located in buildings with basements. It also is the easiest type of release to remediate, as the impact to ground water is minimal.

Another common situation is where perchloroethene is released to a drainage structure — either in the form of separator water or as distillation bottoms — and precipitation causes the perchloroethene to migrate downward to the underlying ground water. A Dense Non-Aqueous Phase Liquid (DNAPL) fraction does not occur (Fig. 3). Perchloroethene concentrations in the ground water are generally in the parts per billion or low parts per million range and occur as a dissolved component of the ground water. This type of release is more difficult to remediate than releases limited to soils in the unsaturated zone.

The third and most difficult type of release to remediate is one where a significant amount of bulk product has been released to the subsurface. This type of release typically occurs as a leak of bulk product from a dry cleaning machine, from a storage tank or from the associated piping (Fig. 4). Releases of this nature are more common in situations where the dry cleaning machine is placed over a concrete slab at grade and there is no basement to serve as a buffer between the machine

and the underlying aquifer. If the release is small in volume, the contamination may be limited to the soil alone. However, if the release occurs over a sufficient period of time, the formation of DNAPL can result in the subsurface. This scenario is by far the most difficult to remediate.

## Available Technology for Soil and Ground Water Remediation

Recent technical advances have provided practicing hydrogeologists and engineers with a tool chest full of solutions to address subsurface PCE releases. Different technologies are applied based on the amount of contaminant released and the manner in which the PCE has migrated within the subsurface.

**PCE releases to subsurface soils above the water table** – If the volume of soil affected by the release is limited, the most economical solution is to excavate the contaminated soil and dispose of it off-site. End-point samples are required to confirm that the contamination has been remediated in accordance with State clean-up guidance objectives. In cases where the release is extensive or excavation is not feasible because of existing structures, Soil Vapor Extraction (SVE) is the best alternative. Slotted pipe is buried below the surface and a vacuum is applied to the soil to remove the trapped perchloroethene vapors. Off-gas controls in the form of granular activated carbon are necessary to treat the extracted vapors.

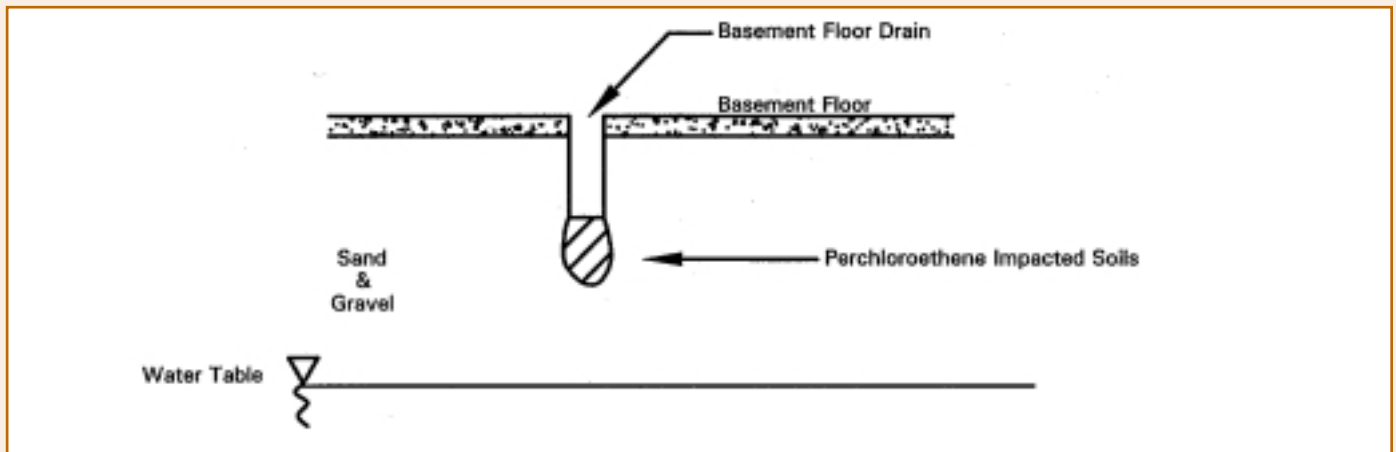


Figure 2. Release Scenario 1 - Release of perchloroethene to soil, minimal impact to groundwater.

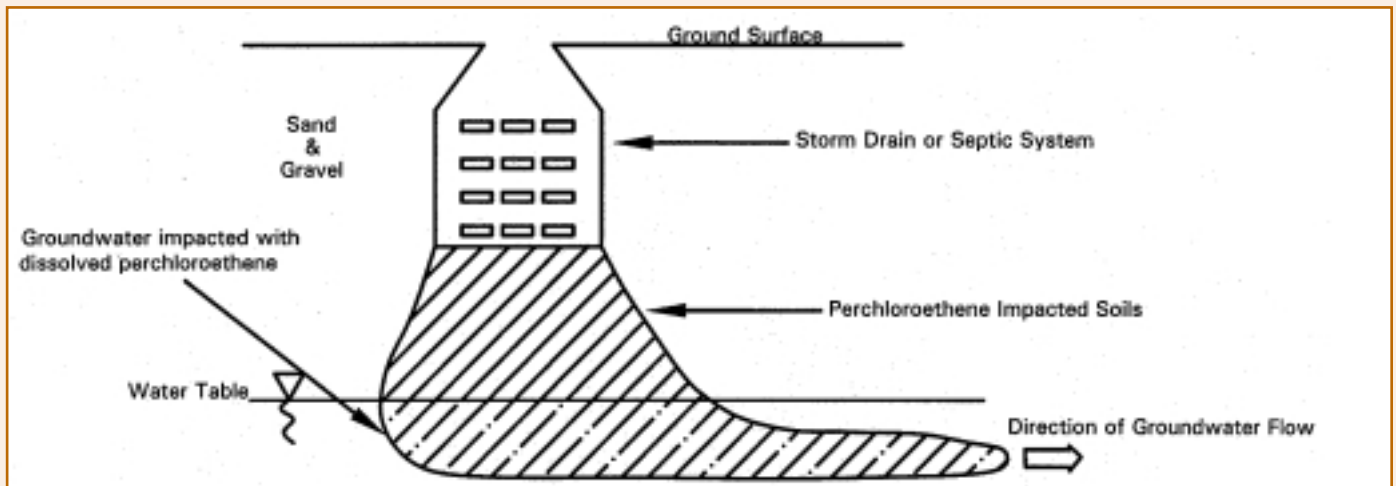


Figure 3. Release Scenario 2 - Release of perchloroethene to soil coupled with dissolved perchloroethene in groundwater.



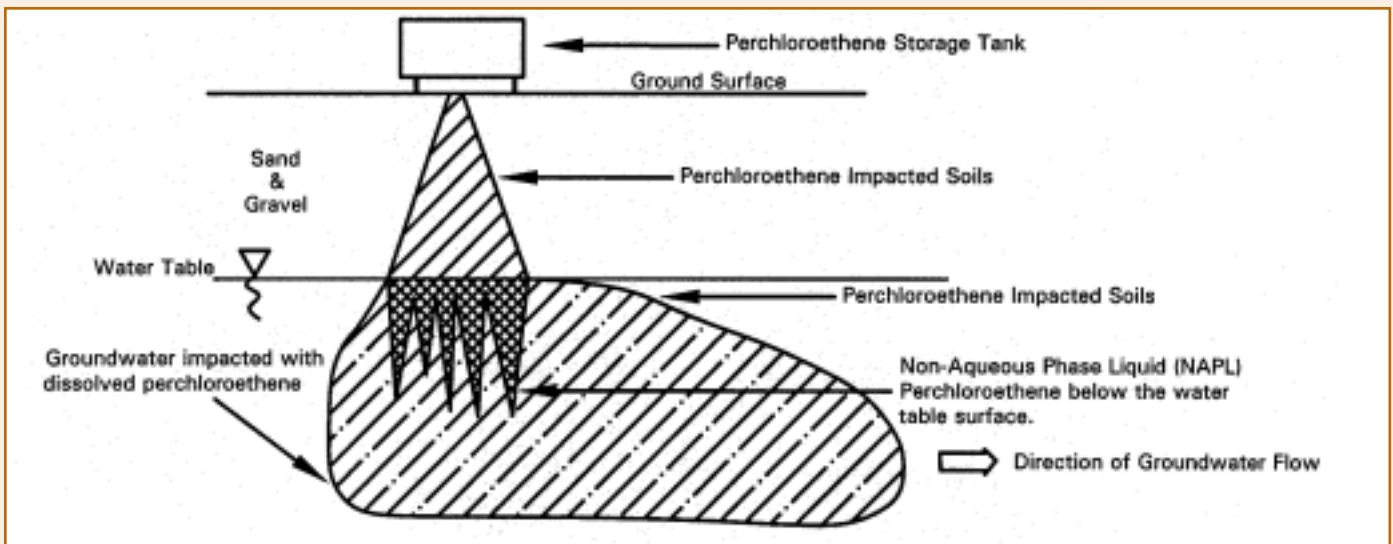


Figure 4. Release Scenario 3 - Release of perchloroethene to soil coupled with both NAPL and dissolved perchloroethene in ground water.

**PCE releases to subsurface soils and within the underlying aquifer –**

The methods for addressing subsurface releases above the water table apply to this type of release as well. The most effective method to treat the underlying ground water is to couple an SVE system with an Air Sparging (AS) unit. By forcing compressed air into the affected aquifer, the dissolved perchloroethene is stripped from the ground water into the overlying soil vapor and then captured by the SVE system. This combined methodology has been widely used during the 1990's and is usually very effective in the sandy soils of Long Island's Upper Glacial Formation. Figure 5 and 6 are examples of a SVE/AS system housed in an equipment shed behind a dry cleaning facility.

Prior to the 1990's, ground water pump and treat systems were applied in the place of air sparging units. As in other areas of the Country, pump and treat technology has its limitations on Long Island (U.S. EPA, 1996). While this is a very effective tool for containing contamination at the property boundary, concentrations of perchloroethene often rebound after the system is shut down. Accordingly, from both a cost and performance standpoint, air sparging is the preferred method of treatment.

Chemical Oxidation is a remediation technique that has recently gained popularity at PCE release sites. Using a strong oxidizing agent – such as potassium permanganate, sodium permanganate, hydrogen peroxide or ozone – PCE dissolved in the ground water is treated in-situ. Fenton's Reagent (hydrogen peroxide plus a metal catalyst) and the permanganate products are injected into the contaminat-



Figure 5 - Equipment shed used to house a soil vapor extraction and air sparging system located behind a dry cleaning facility.



Figure 6. A typical soil vapor extraction and air sparging system used at dry cleaning facilities.

ed portions of the aquifer as a liquid and allowed to react with the subsurface PCE. Several applications of these products are typically required. Ozone is a gas that is used in conjunction with some form of air sparging to destroy PCE in-situ. This is applied continuously over a period of time.

Bioremediation is another alternative method applied to the cleanup of PCE in ground water. Monitored natural attenuation allows ground water professionals the option to demonstrate the subsurface environment's ability to degrade PCE through natural biologic and physical processes. A detailed phase of site characterization is required followed by a program of long-term ground water monitoring. Some of the principles and guidelines regarding where monitored natural attenuation may be applied are provided in U.S. EPA (1997). In addition to the environment's natural processes, attenuation of PCE dissolved in ground water can be enhanced using commercially available products that aid in the growth anaerobic bacteria to help degrade this chemical.

Ground water remediation becomes significantly more difficult when DNAPLs are present within the aquifer. The challenge of remediating DNAPL perchloroethene releases is on the forefront of issues confronting ground water professionals today. In addition to the techniques described above, other remediation efforts that have been applied to DNAPL sites include steam injection, co-solvent flushing and surfactant flushing ITRC (2000). The effectiveness of these methods remain research subjects at some of the more difficult ground water cleanup sites across the Country.

## Summary

A brief history of the development of the dry cleaning industry from the mid 1850's to 2001 is presented above. The two major waste streams generated from dry cleaning plants, distillation bottoms and separator water, are described in detail. These two waste streams, along with accidental releases of bulk product, represent the typical sources of PCE releases.

Three scenarios of typical PCE releases from dry cleaning plants are described. These include: releases to subsurface soils above the water table; releases to soils above the water table and dissolved phase PCE within the underlying ground water; and releases to soils coupled with DNAPL within the underlying aquifer. Practical cleanup technologies for each of these are presented.

Research regarding the remediation of PCE in soil and ground water is ongoing. The State Coalition for Remediation of Drycleaners provides an extensive database including 33 States that lists technologies used to characterize and remediate PCE releases. They can be reached on the web at <http://www.drycleancoalition.org/tech/>. Other web sites, such

as the U.S. EPA's Hazardous Waste Cleanup Information site, <http://www.clu-in.org> also provide ground water professionals with the latest developments in the characterization and remediation of perchloroethene releases.

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