PCB Concentrations at a Karst Spring in Bloomington, Indiana

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Abstract

The Lemon Lane Landfill is an inactive municipal/industrial waste landfill in Bloomington Indiana. The site is located in an area of highly developed karst terrane. Disposal at the site began in the 1930's and ended in 1964. During the last 7 years of operation, scrap PCB capacitors were disposed of at the site. Over the last few years, the karst drainage system impacted by the site has been identified and the relationship between PCB concentrations and flow in the main resurgence of the groundwater, Illinois Central Spring, has been determined. Under non-storm conditions, PCB concentrations at the Spring were found to be inversely related to flow. The response of the spring to storm events is similar to a surface stream, with a rapid rise to a peak flow that is commonly an order of magnitude above base flow, and a recession lasting one to several days depending on the size of the storm and the soil antecedent moisture condition. PCB concentrations during storms were found to vary widely yet consistently depending on when the sample is taken with regards to the progress and magnitude of the storm. The peak PCB concentrations measured at the spring during storms coincided with the arrival of storm water that had rapidly infiltrated to the subsurface conduit system. The total mass of PCBs discharged in the peak period during a storm was found to be a function of the storm's intensity. One implication of these findings is that proper storm water management at the landfill could substantially reduce the mass of PCBs discharged at the Spring.

Introduction

The Lemon Lane Landfill is located on the western side of Bloomington Indiana. This area is in the Mitchell Plain region of Indiana. The Mitchell Plain is a region of relatively low relief underlain by Mississippian age carbonate rocks which has features typical of karst terrane such as sinkholes, subsurface drainage and few surface streams. Karst aquifers are known to be especially prone to contamination from a variety of sources[1].

Uncontrolled disposal at the site began at two sinkholes in the mid-1930's and continued until 1964. During the last 7 years of operation, scrap capacitors containing PCBs were disposed of at the site. Most of the capacitors were scrapped and salvaged at the south end of the landfill. An interim cap, consisting of a 36 mil synthetic impermeable cover, was placed on the site in 1987.

Since 1994, new site investigations have been conducted to determine the extent and nature of groundwater contamination associated with the site. Prior to 1994, groundwater had been sampled in a series of monitoring wells installed adjacent to the site. The use of monitoring wells in such a manner is now recognized as inconsistent with the mechanics of flow in a karst aquifer and the historical monitoring well data was found to be of little value in assessing either the groundwater flow directions or contaminant migration.

Proper methods to investigate the nature and extent of contamination in karst aquifers are described by Quinlan[2]. The methods involve determining where the potential resurgences for groundwater are by performing tracer tests, and then sampling the potential resurgences for the contaminants under varying hydrologic conditions. These methods have been adopted for investigations at this site over the last few years. The springs which receive the groundwater potentially affected by the site have been identified and the PCB concentrations of these springs evaluated. One spring, Illinois Central Spring (ICS), 2000 feet southeast of the landfill was determined to be the main resurgence.

This paper presents PCB and hydrologic data from the ICS from the most recent work that shows how the PCB concentrations vary under different hydrologic conditions. Implications of the data for remedial options are also discussed.

Experimental Methods

A series of monitoring events were conducted at the ICS over a one year period. Both the low flow (or non-storm) and high flow (storm events) conditions were monitored. The ICS was instrumented with an hourly flow, conductivity and temperature recorder. Additionally, water samples for PCB analysis were taken at or near the ICS emergence under various flow conditions.

Under low flow conditions, 1 liter water grab samples were taken by hand dipping the sample container into the emergence point of the spring. The samples were analyzed for total Aroclor PCBs using EPA SW-846 method 8081[3]. Samples were collected at either monthly or weekly frequencies. If a storm occurred near the time the sample was to be taken, then sampling was delayed until flow had receded to 120% of the pre-storm value.

For high flow events a grab sample was taken either by hand dipping a 1 liter bottle into or near the spring emergence, or by pumping through an aluminum tube submerged in the emergence. The pumps used were the peristaltic pumphead portion of the ISCO model 2900 Autosamplers. Storm samples were analyzed as per the non-storm samples.

The frequency of grab sampling during storms varied from 15 minute up to 12 hour intervals. The time interval was adjusted during the event based on changes in spring flow and conductivity.

Results and Discussion

Non-storm Data

Sampling was done at the Illinois Central Spring for PCBs during non-storm conditions from August 1995 through July 1996. The purpose of that sampling was to identify the typical non-storm concentrations at the spring and to determine if they change over a one year time period. Figure 1 is a plot of the PCB concentrations versus spring flow. It appears that the non-storm PCB concentrations are a function of spring flow with lower flows showing higher PCB levels and higher flows lower PCB levels. It was concluded that additional data taken over a longer period of time and flow compensation would be required to discern any temporal trends.

Storm Data

Since May 1995, ten storms ranging in magnitude from 0.64 inches to over 2.44 inches of rain in 24 hours were monitored. Figure 2 is a hydrograph and chemograph from a storm monitored in January 1997. The response of flow, conductivity, and PCB concentrations measured in this storm are similar to the 9 previously monitored storms.

The PCB response can be seen in 4 distinct segments (see Figure 2, segments are labeled I - IV) that have a corresponding conductivity response. The first segment shows consistently low PCB concentrations, similar to pre-storm levels, and fluctuating conductivity values at or above pre-storm levels. The second segment is the peak PCB concentration period which occurs with rapidly declining conductivity. The declining conductivity signals the arrival at the ICS of rain water that has rapidly flowed to the underground conduit system feeding the spring. The third segment is a period of declining PCB concentrations and rising conductivity. It appears to be the period of declining surface runoff contribution to ICS flow. The fourth segment begins when PCB concentrations have receded to approximate pre-storm levels and conductivity has risen to 60 to 70% of its pre-storm value. By this period, surface water infiltration and contribution to ICS flow has ceased.

The PCB mass discharged during a storm appears to be related to the magnitude and intensity of the storm. A simple storm index number has been devised that ranks the storm based on total rainfall, maximum one hour intensity, antecedent moisture conditions, and five day preceding rainfall. Figure 3 is a plot of the natural log of PCB mass discharged under the peak (Segment II) versus the storm index for the 9 storms sampled prior to January 1997. There appears to be a linear relationship between the storm index and the log of PCB mass discharged during the peak period. Other researchers have noted correlations between various aspects of discharge in karst aquifers and similar indices[4]. Such a relationship may prove useful in monitoring storm related discharge over time.

In May 1996, a concurrent tracer test was conducted during storm water monitoring (see Figure 4). A single slug of Fluorescein (Acid Yellow 73) was injected in a macropore (2-3 inch diameter soil pipe visible at the surface) just off the southwest perimeter of the site. Simultaneously, Rhodamine WT (Acid Red 388) was injected in a sinkhole 1000 feet north of the site. The PCB peak coincided with the arrival of the Fluorescein. The Rhodamine WT arrived after the PCB peak had subsided. The Fluorescein breakthrough curve shows the typical pattern of an instantaneous point-source injection with little dispersion occurring during travel to the spring emergence. The similar shape of the PCB concentration curve (high peak to width ratio and rapid decline) implies a slug like injection of PCBs to the aquifer from the vadose zone.

Our interpretation, based on the tracer test and the consistent nature and timing of the PCB peaks in other storms, is that runoff from the southern portion of the cap is rapidly infiltrating into the subsurface near the landfill's southern boundary and is responsible for transporting the PCBs causing the peak during storms. Likely PCB source regions are uncapped soils at the southern perimeter of the landfill or the uppermost portion (first 3 to 5 meters) of the bedrock, the epikarst.

In an attempt to reduce these storm PCB discharges, additional storm run-off controls at the landfill site have been installed. These controls route cap run-off from the southern half of the site to a pond northwest of the site. Additional monitoring to be performed in the spring of 1997 will determine what impact these temporary controls have had. If the PCB storm levels are significantly reduced by these controls, then the best long-term strategy to reduce PCB levels at the ICS may be enhanced surface water controls at the landfill.

Literature Cited

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2. *Groundwater Monitoring in Karst Terranes, Recommended Protocols and Implicit Assumptions*, Quinlan, J. F., EPA/600/x-89/050 March 1989
3. *Test Methods for Evaluating Solid Waste , Physical/Chemical Methods*, US EPA SW-846, Third Edition
4. Smart, P.; Friederich, H., "Water Movement and Storage in the Unsaturated Zone of a Maturely Karstified Carbonate Aquifer, Mendip Hills, England", in *Proceedings of Environmental Problems in Karst Terranes and Their Solutions, Bowling Green, Kentucky 1986*

Figure 1: PCB Concentrations at Non-Storm Flows in ICS

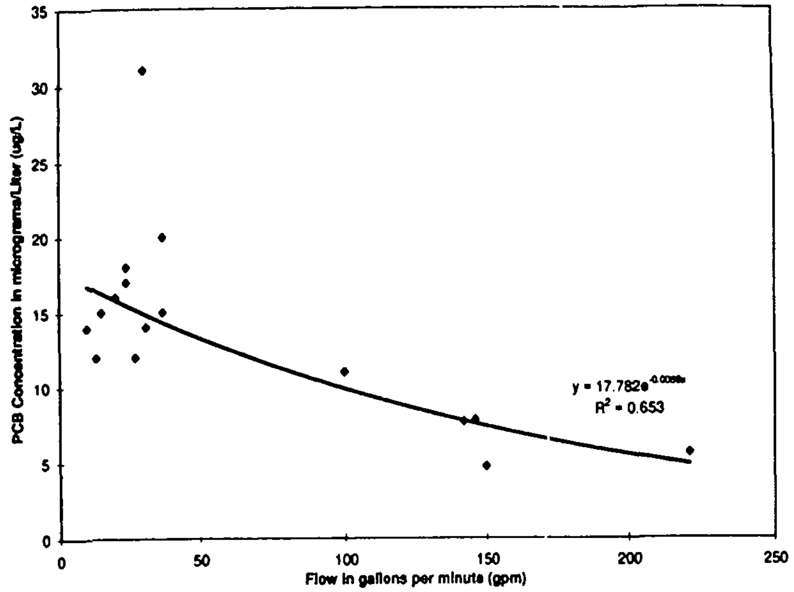

Figure 2: ICS Hydrograph/Chemograph January 1997 Storm. The segments of PCB discharge concentration are seperated by dashed vertical lines.

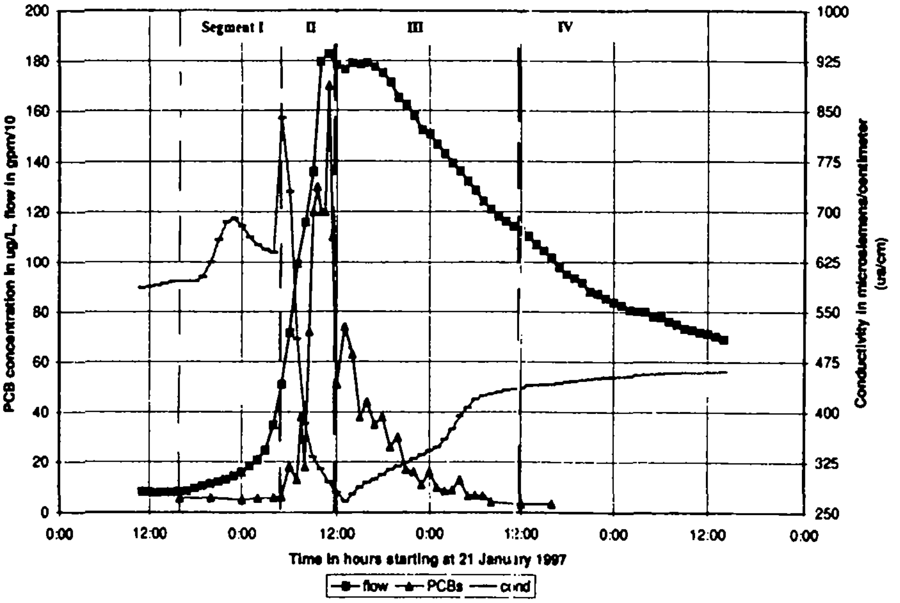

Figure 3: Natural Log (LN) of PCB Mass vs Storm Index
The PCB mass is that associated with the peak PCB period

$R^2 = 0.7565$

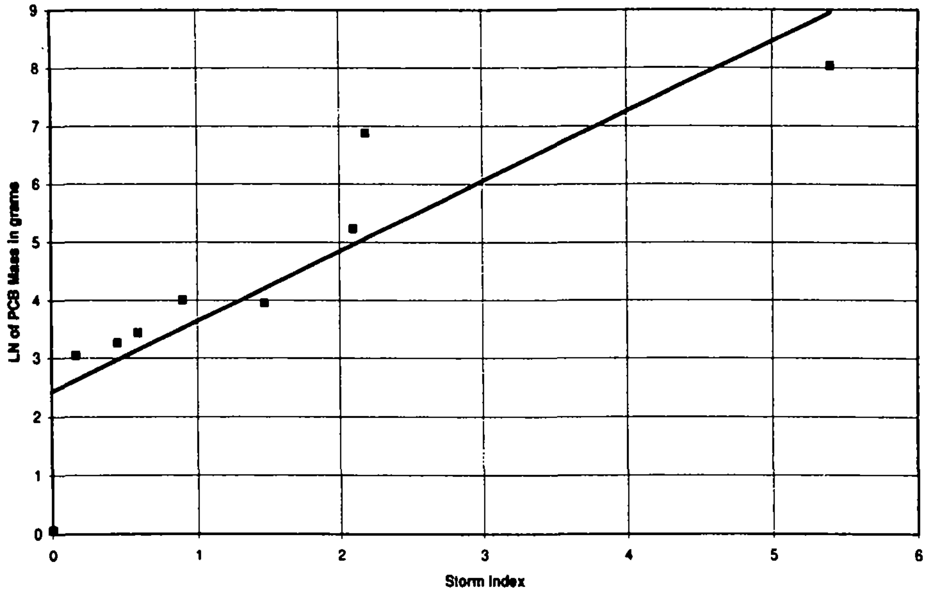

Figure 4: ICS May 1996 Storm Tracer Test Results
Tracers were both injected at 0850 hours. Rain and run-off began at 0800