WA-13-9190GW
92-e42

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
7171 Cleanwater Lane, Building 8, P.O. Box 47710 * Olympia, Washington 98504-7710

August 24, 1992

TO: Dick Heggen
Toxics Cleanup Program

FROM: Pam Marti PRM
Toxics, Compliance, and Ground Water Investigations Section, EILS

SUBJECT: Memorandum on Soil Gas Sampling at the former Hytec Facility in Tumwater

The attached report summarizes the findings from our sampling at the former Hytec facility on December 9-16, 1991.

Results from the soil gas screening suggests that ground water may be contaminated. Trichloroethylene (TCE) was tentatively identified at 12 of 40 locations (30% detection frequency) using the field gas chromatograph. Due to its chemical properties, TCE has proven to be a good compound for soil gas tracking and a good indicator of ground water contamination. Another peak for one or more organic compounds was recorded on the gas chromatograph but could not be identified. In an attempt to verify field soil gas results and identify the unknown compound(s), two soil gas samples (air toxics samples) were collected on May 19, 1992, for laboratory analysis. Unfortunately, the air toxics samples did not confirm the field analyzed TCE detections; nor could any correlation be made between the unknown peak detected in the field to those detected in the air toxic samples.

Since the field gas chromatograph is solely a screening instrument, all identifications are tentative. None-the-less the presence of peaks on the chromatographs does seem to indicate the possibility of ground water contamination.

Soil samples were also collected during this study. One soil sample, near the former tank site, showed elevated concentrations of acetone and ethylbenzene. Several priority pollutant semi-volatiles were also detected in soil samples from the suspected spill area and the former tank area. Cobalt was elevated relative to background concentrations in one sample; chromium appeared to be elevated in three samples.

I would like to take this opportunity to thank you for allowing us to conduct our first soil gas study on one of your projects. This has been a valuable learning experience in regards to both project design and field work. We have gained a lot of knowledge and look forward to

implementing all that we've learned in the next project. I look forward to providing any soil gas service to you in the future. If you have any questions or comments please call me at 586-8138.

PM:krc
Attachment

cc: Bill Yake
Denis Erickson

HYTEC SOIL GAS SURVEY
TUMWATER, WASHINGTON
DECEMBER 9-16, 1991

---

by Pamela B. Marti
July 27, 1992

Washington State Department of Ecology
Environmental Investigations and Laboratory Services Program
Toxics, Compliance and Ground Water Investigations Section
Olympia, Washington 98504-7710

Water Body No. WA-13-9190-GW
(Segment No. 06-13-03-GW)

SUMMARY

Soil gas and soil samples were collected as part of a preliminary Site Hazard Assessment (SHA) on December 9-16, 1991, at the former Hytec fiberglass manufacturing facility in Tumwater, Washington. A total of 40 soil gas samples and 12 soil samples were collected and tested to provide information on the extent of on-site soil contamination and potential ground water contamination. This information will be used to score and rank the site using the Washington Ranking Method (WARM). Soil gas samples were analyzed in the field using a portable gas chromatograph. Trichloroethylene (TCE) was tentatively identified at 12 of 40 locations (30% detection frequency). Estimated TCE concentrations ranged from 1.8 to 53 ppb. The presence of TCE in soil gas samples suggests that ground water may be contaminated. Peaks for one or more organic compounds were recorded on the gas chromatograph but could not be identified. On May 19, 1992, two soil gas samples (air toxics samples) were collected and analyzed in the laboratory to verify field soil gas results. Field analyzed TCE detections were not confirmed with the air toxics samples. No correlation could be made between unknown peaks detected in the field soil gas samples and the air toxic samples. One soil sample, near the former tank site, showed elevated concentrations of acetone and ethylbenzene. Eleven priority pollutant semi-volatiles were detected in soil samples from the suspected spill area and the former tank area. Cobalt was elevated relative to background concentrations in one sample; and chromium appeared to be elevated in three samples.

OBJECTIVES

Survey objectives were to provide information on the extent of on-site soil contamination and potential ground water contamination so that the site could be ranked using WARM. Tasks to meet these objectives are as follows:

- Conduct a soil gas survey to provide information on the extent of selected volatile organics in on-site ground water and soil;
- Obtain and test soil samples for a broad range of organic contaminants in suspected spill areas; and
- Verify field soil gas results with laboratory-analyzed soil gas samples (air toxics analysis).

SITE BACKGROUND

Hytec, a fiberglass manufacturer formerly located at 711 Airdustrial Way, Tumwater, Washington, is suspected of illegally disposing waste chemicals based on complaints filed with the Department of Ecology in 1985 and 1986. Barrels of waste chemicals reportedly were decanted to a storm drain which discharged to a swampy area near the Hytec site. Six hundred gallons of waste per month were reported to be dumped for an unspecified period. Wastes included such chemicals as acetone, methylene chloride, methyl-ethyl ketone peroxide, dimethylamine, tricresyl phosphate (TCP) and polyester resins. The suspected spill area is near two City of Tumwater water-supply wells (Figure 1).

A 1500 gallon acetone spill was also reported to have occurred near outside storage tanks which were located at the southeast corner of the building (Heggen, 1991).

At one time the property south of the site had been used by the military during World War II. Large cement blocks south of the fenceline were identified as remnants of military structures (Port of Olympia, 1991).

The property is owned by the Port of Olympia and is currently being leased by The Great American Herb Co. which has occupied the premises for the past three years. Operations at this facility involves drying herbs, adding synthetic fragrances and packaging herbs (Armitage, 1991).

Surface geology of the area is predominately Vashon Drift which is composed of recessional sand and gravel, till, and advanced outwash (USGS, 1961 & 1966). The well log for the City of Tumwater well #9 shows 15 feet of fine sand overlying interlayered sand and gravel to the bottom of the hole (105 feet). These deposits are highly permeable and allow for rapid percolation of water to the water table. Well #9 is located approximately 125 feet west of the suspected spill area. The depth to the water table is estimated to fluctuate seasonally between 3 to 13 feet.

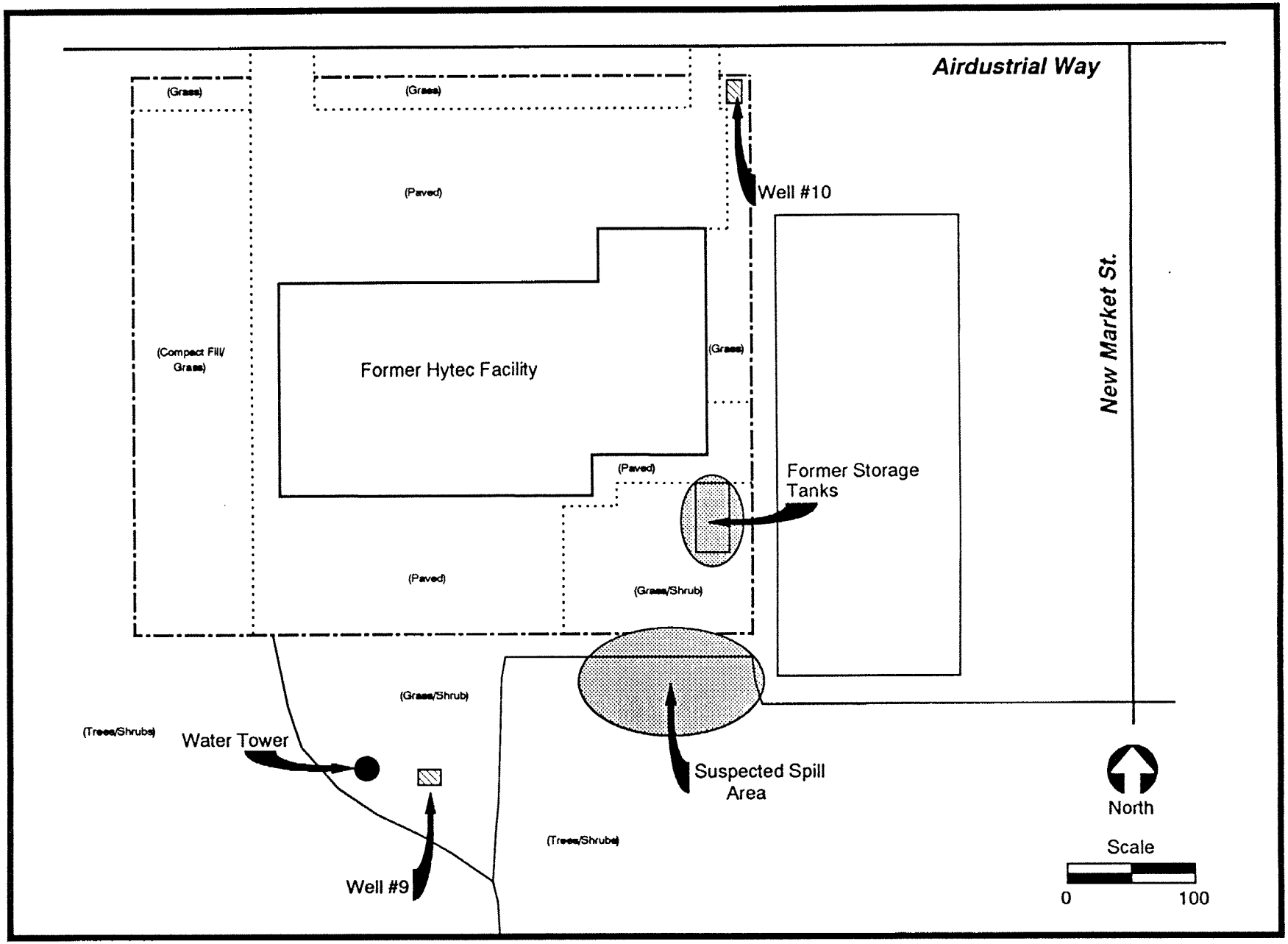

Figure 1: Site Map

METHODS

Sample Collection

Pam Marti and Denis Erickson conducted the initial soil gas and soil sampling on December 9-16, 1991. Weather conditions were cold and clear, with occasional showers throughout the week. Soil gas samples (air toxics samples) were collected on May 19, 1992, and sent to the laboratory for analysis to verify field soil gas results. The weather was warm and clear.

Soil Gas Sampling

Forty soil gas samples were obtained using portable sampling equipment. A pilot hole was drilled to the required depth using a 1/2-inch diameter, solid steel rod. After removing the pilot hole rod, a stainless steel retractable soil gas sampling tip (Retract-a-Tip) was driven into the pilot hole. The retractable tip was then pulled back (about 2 inches) to expose the sampling screen. Soil gas samples were withdrawn using a suction pump through 3/16-inch ID teflon tubing and collected under vacuum pressure in 1 liter Tedlar bags. Air toxics samples were collected through the Retract-a-Tip under vacuum of the 6 liter stainless steel sample container.

Depth profile sampling was conducted at two of the sample locations, HSG1 and HSG18 to determine an appropriate sample depth. Soil gas samples were collected at two foot intervals down to eight feet. Based on depth profile results, soil gas samples were obtained from a depth of three feet in the suspected spill area and the former storage tank area and a depth of six feet over the remainder of the site.

Soil gas samples were analyzed in the field using a portable gas chromatograph (Sentex Scentograph Plus), equipped with an Argon Ionization Detector (AID) and a 12' 10% SP-1000 (80/100 mesh) packed column. Prior to sample analysis the gas chromatograph was calibrated using a mixture of 0.98 ppm benzene and 0.94 ppm trichloroethylene. Operating parameters were set so that calibration peaks coincided with retention times established on an industrial solvents chemical compound library (Sentex). The chemical compound library was used to identify on-site contaminants. Only the 19 compounds that exist on the library could have been identified. These compounds are listed in Appendix A.

Prior to air toxic sampling on May 19, soil gas samples were collected and analyzed on the portable gas chromatograph. Due to operational difficulties with the 12' packed column, a 6' 3%SP-1000 (100/120 mesh) packed column was used with the argon ionization detector. This column does not have a compound library, therefore only the compounds in the calibration gas could be used for identification of on-site contaminants.

Operating parameters such as sample time, temperature, and chart duration were adjusted in the field to maximize results. Hard copies of all soil gas analysis, as well as operating parameter information are included in Appendix A.

All non-dedicated down-hole equipment was decontaminated between test holes using a tap water/Liquinox® wash and sequential rinses with deionized water and laboratory grade methanol. Retractable tips were completely disassembled for cleaning and decontaminated between holes. Teflon® tubing was discarded between test holes.

Soil Sampling

Soil samples were collected from selected locations using the JMC portable soil sampler. A hollow, 3-foot-long, one-inch diameter sampling tube fitted with a stainless steel liner was driven through the soil column. All downhole soil sampling equipment was decontaminated using a tap water/Liquinox® wash and sequential rinses with deionized water and laboratory grade methanol. The sampling tube was then pulled from the hole and the liner removed from the sampler. Soil samples corresponding to the soil gas sample depth were extracted from the liner, sealed in 4 ounce glass jars and sent to the laboratory for testing. For deeper samples, extensions were attached to the sampling tube and driven to the required depth. Test holes were plugged using hydrated bentonite. Overlying fill and asphalt cover (cold mix) were placed as necessary.

All soil samples were analyzed for volatile organic compounds (VOCs). Samples collected from the suspected spill area were also analyzed for semi-volatile organics and priority pollutant metals. Chemical analyses, analytical methods, and detection limits for soil samples are shown in Table 1.

Table 1: Parameters, Analytical Methods and Detection Limits for Soil Samples

Parameters	Analytical Method	Reference	Detection Limit
Volatile Organics:	#8260	EPA SW846 1986	5 μg/kg
Semi-Volatile Organics:	#8270	EPA SW846 1986	100-200 μg/kg
Metals:			
Antimony	#7041	EPA CLP SOW 1991	0.1 mg/kg
Arsenic	#7060	EPA CLP SOW 1991	0.15 mg/kg
Beryllium	#6010	EPA CLP SOW 1991	0.1 mg/kg
Cadmium	#6010	EPA CLP SOW 1991	0.2 mg/kg
Chromium	#6010	EPA CLP SOW 1991	0.5 mg/kg
Cobalt	#6010	EPA CLP SOW 1991	0.5 mg/kg
Copper	#6010	EPA CLP SOW 1991	0.2 mg/kg
Lead	#7421	EPA CLP SOW 1991	0.1 mg/kg
Mercury	#245.5	EPA CLP SOW 1991	0.004mg/kg
Nickel	#6010	EPA CLP SOW 1991	1.0 mg/kg
Selenium	#7740	EPA CLP SOW 1991	0.2 mg/kg
Silver	#6010	EPA CLP SOW 1991	0.2 mg/kg
Thallium	#7841	EPA CLP SOW 1991	0.25 mg/kg
Zinc	#6010	EPA CLP SOW 1991	0.2 mg/kg

Quality Assurance Samples

Soil Gas

In general, soil gas results are considered to be good and usable. Soil gas quality assurance samples consisted of calibration and quality control standards, duplicates, and blanks. The gas chromatograph was calibrated at least once every five analytical runs with a standard pressurized mixture of 0.98 ppm benzene and 0.94 ppm trichloroethylene. Operating parameters were adjusted as needed to maintain correlation between the calibration and chemical compound library. A quality control standard which consisted of a Tedlar bag filled with the benzene/trichloroethylene calibration mixture was used to estimate analytical accuracy. Duplicate samples (repeat analysis of the same sample) were analyzed at least 10% of all soil gas samples. In general, duplicate results were good. Blank samples were run periodically to ensure that no contamination of the analytical system had occurred.

Soil Samples

Stuart Magoon and Arthur Hedley of the Manchester Laboratory evaluated quality assurance results which are included in Appendix B. The quality of the organic results is good. Acetone was detected at or near the detection limit in both method blanks and in all but one sample (HSG10). Quality of the metals results is fair. Most metals analyzed for were detected; however, most results have been qualified as estimates (See Table 3). Copper and zinc results are qualified with an "E" indicating the presence of an interference during the analysis. Spike recoveries for most analytes were within acceptable limits of 75-125%, with the exception of lead and chromium. Relative percent differences (%RPD) for the spike and spike duplicates were within $\pm 20\%$.

RESULTS AND DISCUSSION

Soil Gas

Soil gas sample results are useful for determining the extent of contamination for analytes that partition to the gas phase. Table 2 presents the soil gas survey results. Trichloroethylene (TCE) was tentatively identified as the primary contaminant detected on-site. TCE is considered a good compound for soil gas identification of ground water contamination because of its high vapor pressure and low aqueous solubility (Marrin, 1987). It was detected in 12 (30%) of the 40 soil gas samples analyzed. Estimated TCE concentrations ranged from 1.8 to 53 ppb. TCE was detected predominately in the southeast section of the study area, as shown in Figure 2. TCE concentrations also appeared to increase with depth at profile sample location HSG18. Concentrations at depths of 2, 6, and 8 feet were estimated to be 23, 24, and 40 ppb, respectively. Increasing TCE concentrations with depth suggest that ground water may be contaminated.

Table 2

Soil-Gas Results collected Dec.9-16, 1991 from Hytec Fiberglass Manufacturing Tumwater, WA

NOTE: **Analytes are considered tentatively identified and concentrations are estimates.**

Sample #	Sample I.D.	Depth (feet)	TCE Retention Time (seconds)	TCE Estimated Concent. (ppb)		m-Xylene# Retention Time (seconds)	m-Xylene# Estimated Concent. (ppb)		Styrene Retention Time (seconds)	Styrene Estimated Concent. (ppb)		Unknowns Retention Time (seconds)	Unknowns Estimated Concent. (ppb)	
2	HSG1a	2	-	-		-	-		-	-		765	140	
3	HSG1b	4	-	-		-	-		-	-		-	-	
7	HSG1c	6	-	-		-	-		-	-		-	-	
8	HSG1d	8	-	-		-	-		-	-		-	-	
11	HSG2	3	-	-		-	-		-	-		-	-	
14	HSG3	3	-	-		-	-		-	-		-	-	
16	HSG4	3	-	-		648	340	NJ	1102	9600	NJ	374	53	NJ
18	HSG4DUP		267	20	NJ	-	-		-	-		658	1300	NJ
19	HSG5	3	267	1.8	NJ	-	-		-	-		662	210	NJ
21	HSG6	3	268	6.2	NJ	-	-		-	-		663	350	NJ
22	HSG7*	3	-	-		-	-		-	-		664	180	NJ
24	HSG8	3	-	-		-	-		-	-		664	150	NJ
25	HSG9	3	-	-		-	-		-	-		-	-	
28	HSG10	3	-	-		-	-		-	-		797	43	
30	HSG11	3	-	-		-	-		-	-		813	150	NJ
31	HSG12	3	-	-		-	-		-	-		822	210	NJ
33	HSG13	3	-	-		-	-		-	-		824	230	NJ
34	HSG14	3	306	15	NJ	-	-		-	-		825	590	NJ
35	HSG15	3	-	-		-	-		-	-		828	200	NJ
36	HSG16	3	-	-		-	-		-	-		-	-	
37	HSG17	3	310	30	NJ	-	-		-	-		832	450	NJ
40	HSG18a	2	296	23	NJ	-	-		-	-		794	260	NJ
41	HSG18b	4	-	-		-	-		-	-		798	72	NJ
42	HSG18c	6	300	24	NJ	-	-		-	-		803	330	NJ
43	HSG18d	8	300	40	NJ	-	-		-	-		807	640	NJ
44	HSG18DUP		302	18	NJ	-	-		-	-		813	430	NJ
45	HSG19	6	307	23	NJ	-	-		-	-		824	1000	NJ
47	HSG20	6	-	-		-	-		-	-		823	450	NJ
48	HSG21	6	-	-		-	-		-	-		827	320	NJ
49	HSG22	6	-	-		-	-		-	-		827	260	NJ
50	HSG23	6	-	-		-	-		-	-		-	-	
52	HSG24	6	-	-		-	-		-	-		-	-	
53	HSG25	6	-	-		-	-		-	-		787	92	NJ
54	HSG26	6	-	-		-	-		-	-		790	260	NJ
55	HSG27	6	-	-		-	-		-	-		788	160	NJ
56	HSG28	6	294	42	NJ	-	-		-	-		792	390	NJ
57	HSG28DUP		296	53	NJ	-	-		-	-		795	380	NJ
61	HSG29	6	-	-		-	-		-	-		805	15	NJ
62	HSG30	6	-	-		-	-		-	-		-	-	
63	HSG31	6	300	11	NJ	-	-		-	-		814	96	NJ
64	HSG32	6	-	-		-	-		-	-		-	-	
66	HSG33	6	-	-		-	-		-	-		770	110	NJ
67	HSG34	6	287	17	NJ	-	-		-	-		774	150	NJ

* = Designated background sample.

NJ = Tentatively identified compound. Associated numerical result is an estimate.

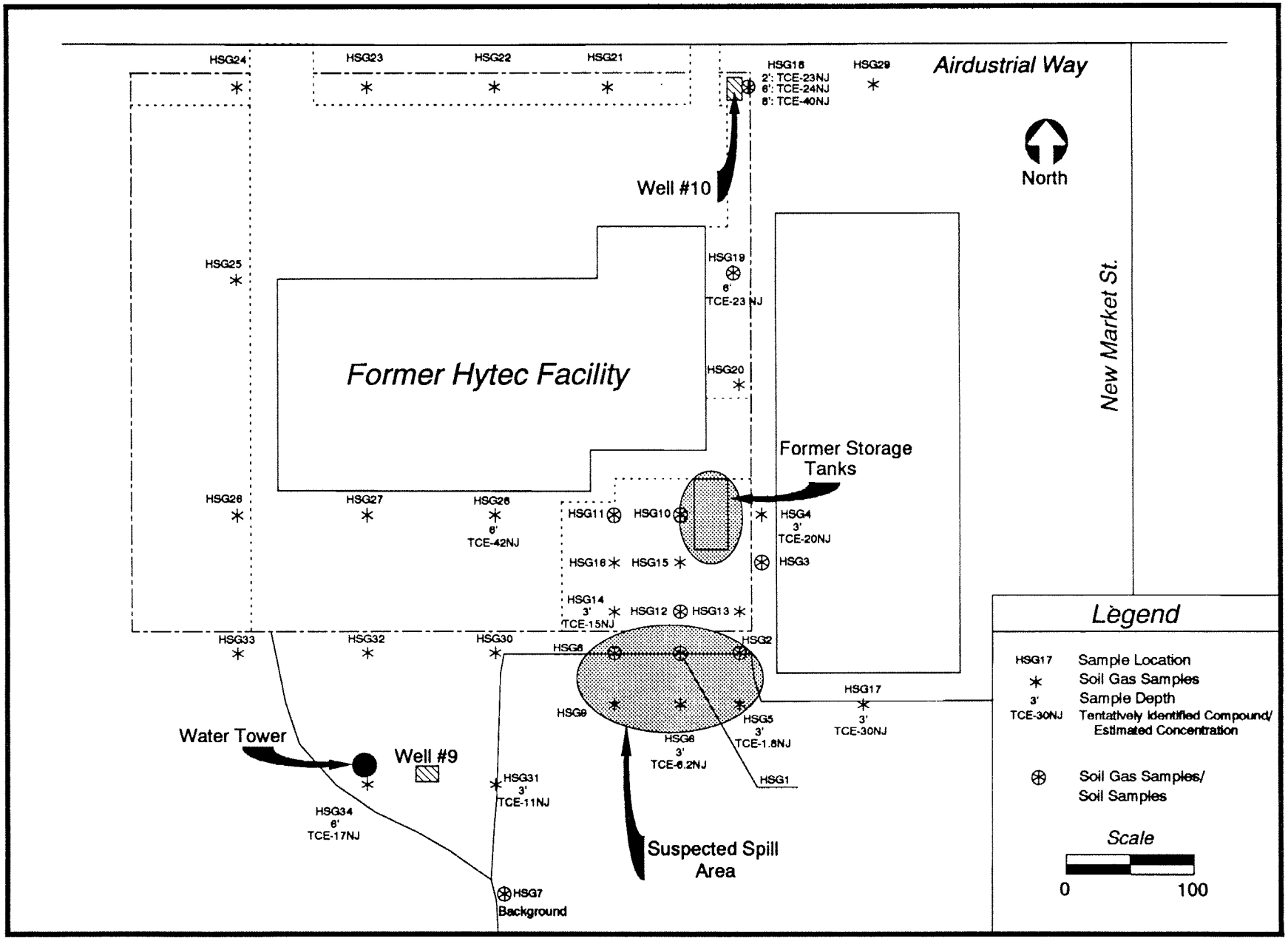

Figure 2: Soil Gas Sample Locations and Trichloroethylene (TCE) Results (PPB)

The two air toxics samples collected on May 19, 1992, at sample locations HSG14 and HSG18 were analyzed in the laboratory to verify field soil gas results. Field analyzed TCE detections were not confirmed with the air toxics samples.

Dichloro-difluoromethane and trichlorofluoromethane were detected at HSG14 at 7J mg/m^3 and 480 mg/m^3, respectively. Trichlorofluoromethane (3J mg/m^3) and tetrachloroethylene (8J mg/m^3) were detected at HSG18. Additional compounds tentatively identified are listed in Appendix C.

m-Xylene (340 ppb) and styrene (9600 ppb) were also tentatively identified in the field analyzed soil gas samples. These compounds were detected adjacent to the former storage tanks in sample HSG4. Peaks for one or more organic compounds were observed on the chromatographs but could not be identified using the gas chromatograph chemical library. The unknown compound was detected in the majority of the soil gas samples (77%) and over most of the study area. Due to retention time drift on the gas chromatograph it is uncertain if the unknown represents more then one compound. No correlation could be made between unknown peaks detected in the field soil gas samples and the air toxic samples.

A background sample (Figure 2) was tested from an area considered to be upgradient of the suspected spill site. An unknown compound was detected in the background sample.

Soil Samples

Soil sample results are used to define the extent of contamination for analytes that partition to soil water or the soil matrix. Soil samples from some sites within the study area showed detections of several volatile and semi-volatile organics and moderately elevated concentrations of cobalt and chromium relative to background (HSS7). The sample results are shown in Table 3. Toluene was detected in most of the samples at low concentrations. The highest concentrations of acetone (67 μg/kg) and ethylbenzene (830 μg/kg) were detected in sample HSS10 adjacent to the former tank site. Possible reasons that these compounds were not detected in the soil gas are: (1) acetone is very soluble and tends to remain dissolved in water, such as ground water or soil pore water; and (2) ethylbenzene tends to stay near the source and can be degraded by oxidation in shallow soils (Marrin, 1987).

Eleven semi-volatile organics were detected in the soil samples as shown in Table 3. Identified semi-volatiles and maximum observed concentrations are benzo(a)anthracene (110 μg/kg), benzoic acid (7700 μg/kg), phenanthrene (35J μg/kg), pentachlorophenol (190J μg/kg), 1,2-dichlorobenzene (44J μg/kg), 1,4-dichlorobenzene (20J μg/kg), bis(2-ethylhexyl)phthalate (6500 μg/kg), 1,2,4-trichlorobenzene (13J μg/kg), dimethylphthalate (42J μg/kg), chrysene (100 μg/kg), and retene (780 μg/kg). Most of these detections occurred in two samples HSS1, in the suspected spill area, and HSS3, adjacent to the former storage tank area.

Five soil samples were tested for priority pollutant metals. Analytical results for the soil samples are presented in Appendix B. Cobalt was detected in one sample (HSS1) at 31 ppb, about four times higher than background (HSS7). Chromium was detected in three samples at concentrations about two times higher than background.

Table 3: Summary of Analytical Results from Soil Samples collected December 9–16, 1991, Hytec Fiberglass Manufacturing Tumwater, WA

NOTE: Soil sample identification numbers correspond to soil-gas sample location numbers.

Sample Identification	HSS1	HSS1a	HSS2	HSS3	HSS7*	HSS8	HSS10	HSS11	HSS12	HSS18a	HSS18d	HSS19
Sample Depth	0.0'	0.0-3.0'	0.6-2.0'	0.0-3.0'	2.0-3.0'	2.0-3.0'	0.8-2.0'	1.0-1.3'	2.0-3.0'	2.0-3.0'	8.0'	6.0'
Volatile Organics (µg/kg)							*					
Acetone	5 UJ	10 UJ	10 UJ	10 UJ	12 U	12 U	67	10 UJ	12 U	12 U	10 UJ	10 UJ
Benzene	6 U	6 U	6 U	6 U	6 U	6 U	6 U	2 J	1 J	6 U	6 U	6 U
Toluene	2 J	2 J	2 J	5 J	1 J	1 J	4 J	6 J	6 J	6 U	6 U	6 U
Ethylbenzene	6 U	6 U	6 U	6 U	2 J	6 U	830	4 J	6 U	6 U	6 U	6 U
Xylene (total)	6 U	6 U	6 U	6 U	6 U	6 U	3 J	2 J	1 J	6 U	6 U	6 U
Semi-Volatile Org. (µg/kg)												
Benzo(a)anthracene	110	87 U	NT	91 U	100 U	NT	90 U	NT	NT	NT	NT	NT
Benzoic acid	7700	99 J	NT	1200 U	1300 U	NT	350 J	NT	NT	NT	NT	NT
Phenanthrene	35 J	87 U	NT	91 U	100 U	NT	90 U	NT	NT	NT	NT	NT
Pentachlorophenol	190 J	450 U	NT	470 U	520 U	NT	460 U	NT	NT	NT	NT	NT
1,2-Dichlorobenzene	98 U	87 U	NT	44 J	100 U	NT	90 U	NT	NT	NT	NT	NT
1,4-Dichlorobenzene	98 U	87 U	NT	20 J	100 U	NT	90 U	NT	NT	NT	NT	NT
bis(2-ethylhexyl)phthalate	6500	87 U	NT	160 U	160 U	NT	90 U	NT	NT	NT	NT	NT
1,2,4-Trichlorobenzene	98 U	87 U	NT	13 J	100 U	NT	90 U	NT	NT	NT	NT	NT
Dimethylphthalate	98 U	87 U	NT	91 U	100 U	NT	42 J	NT	NT	NT	NT	NT
Chrysene	100	87 U	NT	91 U	100 U	NT	90 U	NT	NT	NT	NT	NT
Retene	98 U	87 U	NT	780	84 J	NT	79 J	NT	NT	NT	NT	NT
Total Metals (mg/kg)												
Arsenic	3.98	1.85	NT	2.76	3.25	NT	3.51	NT	NT	NT	NT	NT
Berylium	0.45 P	0.54	NT	0.48 P	0.64	NT	0.5	NT	NT	NT	NT	NT
Cadmium	0.47 P	0.32 P	NT	0.38 P	0.5 P	NT	0.35 P	NT	NT	NT	NT	NT
Chromium	50.6 N	27.6 N	NT	45.2 N	28.5 N	NT	64 N	NT	NT	NT	NT	NT
Cobalt	31.3	6.23	NT	6.41	6.95	NT	7.64	NT	NT	NT	NT	NT
Copper	13.9 E	13.3 E	NT	14.1 E	15.9 E	NT	15.5 E	NT	NT	NT	NT	NT
Lead	6.83 N	2.98 N	NT	5.96 N	7.38 N	NT	7.68 N	NT	NT	NT	NT	NT
Mercury	0.029 PB	0.018 PB	NT	0.023 PB	0.027 PB	NT	0.039 PB	NT	NT	NT	NT	NT
Nickel	26.4	28	NT	27.9	27.4	NT	27.3	NT	NT	NT	NT	NT
Zinc	38.5 E	35.7 E	NT	72.4 E	39.7 E	NT	45.9 E	NT	NT	NT	NT	NT

U: The analyte was not detected at or above the associated value.

J: The associated numerical value is an estimated quantity.

UJ:The analyte was not detected at or above the associated estimated value.

B: Analyte was also found in the analytical method blank indicating the sample may have been contaminated.

P: The analyte was detected above the instrument detection limit but below the established minimum quantitation limit.

N: The spike sample recovery is not within control limits.

E: Reported result is an estimate because of the presence of interference.

NT: Not Tested

* = Background sample

REFERENCES

Armitage, H.D., 1991. Controller of Great American Herb Co. Personal Communication, October 1991.

EPA, 1986. Test Methods for Evaluating Solid Waste, SW-846. Office of Emergency Response, Washington, D.C.

EPA, 1991. EPA Contract Laboratory Program Statement of Work, 1991.

Heggen, R., 1991. Personal Communication with former employee of Hytec. November 1991.

Huntamer, D. and J. Hyre, 1991. Manchester Environmental Laboratory - Laboratory Users Manual. July 1991.

Marrin, D.L., 1987. Soil Gas Sampling Strategies: Deep vs. Shallow Aquifers, proceedings of the First National Outdoor Action Conference on Aquifer Restoration, Ground Water Monitoring, and Geophysical Methods. National Water Well Association, May 18-21, 1987, Las Vegas, Nevada.

Port of Olympia, 1991. Personal Communication with Port of Olympia official. December 1991.

U.S. Geological Survey, 1961. Water Supply Bulletin No. 10. Geology and Ground-Water Resources of Thurston County, Washington. Vol. 1, 1961 & Vol. 2, 1966.