MTBE AND BTEX STRIPPING DURING BUBBLEX[SM] TWO-PHASE EXTRACTION

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ABSTRACT:

This paper presents the results of hydrocarbon stripping data from five stripping tests performed using the patented (Patent No. 5,906,241) Bubblex[SM] two-phase extraction and hydrocarbon stripping method. The method extracts water and strips volatile hydrocarbons from the water during two-phase extraction (active water and vapor extraction).

The stripping test consists of collecting several water samples from the extraction well and from the extraction pipe between the wellhead and discharge point or storage tank. The changes in hydrocarbon concentrations due to stripping in the extraction pipe were tabulated and compared with the vacuum, depth to water, vapor and water flow-rates.

The results of all five tests showed a MTBE stripping ratio ranging between 47% and 98%, and BTEX stripping ratio ranging between 40% and >99%. The test results also showed that the stripping ratio is higher when (1) the extraction vacuum is higher, (2) water flow rate is lower, (3) vapor flow rate is higher, and (4) groundwater in the extraction well is deeper. It was also observed that the BTEX stripping ratio was about 20 to 30% higher than the MTBE stripping ratio, with one exception (Test IV – Yorba Linda Site).

This paper concludes that two-phase extraction can be used as an effective extraction and stripping tool for VOC contaminated groundwater.

INTRODUCTION

The purpose of this paper is to provide stripping data from five Bubblex[SM2] two-phase extraction-stripping tests. The uniqueness and interest to the scientific community of these tests is that a new method of two-phase extraction was used with emphasis on in well stripping of the volatile hydrocarbons (VOCs).

In this paper, we present a brief overview of the two-phase extraction with emphasis on Bubblex[SM] modifications followed by the results of five stripping tests, summary discussions and conclusions.

[1] Currently with Department of Toxic Substances Control, Glendale, California
[2] Bubblex[SM] is a service mark of Tait Environmental Management, Inc.

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Method Description: *Two-phase extraction* is a method of vapor and water removal in a combined flow stream using a vacuum force. Several references related to scattered use of two-phase extraction, multiphase extraction and dual phase extraction methods for environmental clean up can be found in the literature going back several years (Morrow, 1991; Mancini et al, 1994; Baker, 1996). The *term "two-phase extraction"* and *"dual phase extraction"* has been used interchangeably in several articles. However, in this paper, the authors reserve the term *"two-phase extraction"* for simultaneous extraction of the vapor and water in a combined flow stream as opposed to *"dual phase extraction"* which is simultaneous extraction of both vapor and water using two separate flow streams (i.e. down-hole pumps for water and vacuum pumps for vapor). The authors use the term *"multiphase extraction"* for the extraction of vapor, water and free phase hydrocarbons in a common stream. The Bubblex[SM] two-phase extraction method uses one common flow stream for both vapor and water.

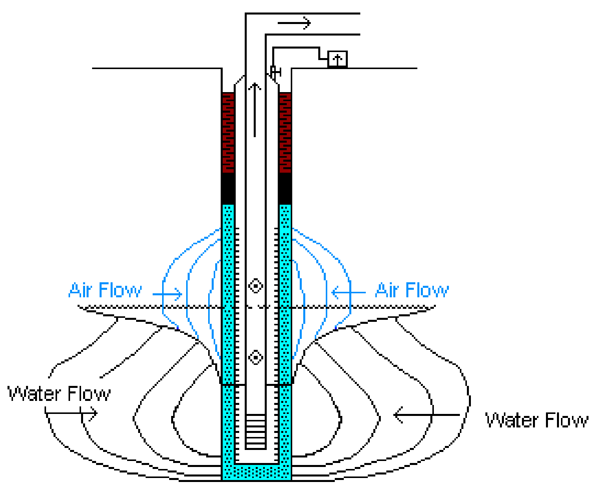

Figure 1 Extraction Well Detail
(Pehlivan and Beaty, 2000)

A major challenge of performing two-phase or multiphase extraction lie with overcoming the limitations of the vacuum when extracting water from depths greater than 33 feet (10.06 m) below ground surface (BGS). The maximum available vacuum lift on Earth for water is 33.9 feet (10.33 m; 29.92-inches [76 cm] of mercury) which is the displacement of the Earth's atmospheric pressure. In addition to the Bubblex Method, there are two patented methods to overcome the difficulties associated with the lifting water greater than 33 feet using vacuum extraction. The first method involves injecting air into the extraction pipe below the water table with an air injection pipe placed inside the extraction pipe (Morrow, 1991). The second method involves injecting air into the extraction pipe below the water table by the use of an external injection pipe connected to the side of extraction pipe (Mancini et al, 1994). In addition to these two patented methods, bioslurping was used to extract free floating hydrocarbons and water from the subsurface by placing the extraction pipe intake at the water table (Baker, 1996).

The Bubblex[SM] method allows a limited amount of air/vapor from the unsaturated zone and a limited amount of water from the saturated zone to enter the extraction pipe through a modified screen. The modified screen is prepared by placing slots and/or orifices on the extraction pipe above and below the water table. When vacuum is applied to the extraction pipe, water from the screen below the water table and vapor from the orifices above the water table enter into the extraction pipe and flow in a common stream. Both vapor and water flow in a combined stream within the extraction pipe until it reaches the separation tank. The new design of the extraction pipe screen facilitates lifting water from depths greater than 33 feet (10.06 meters), extracting vapor from the vadose zone and stripping volatile hydrocarbons from the extracted water (Figure 1). The extracted water and vapor are then separated in a separation tank. The vapor is sent to a thermal/catalytic oxidizer, and the water is discharged through an granulated activated carbon (GAC) polishing unit to a storm drain under a National Pollution Discharge Elimination System (NPDES) permit (Figure 2).

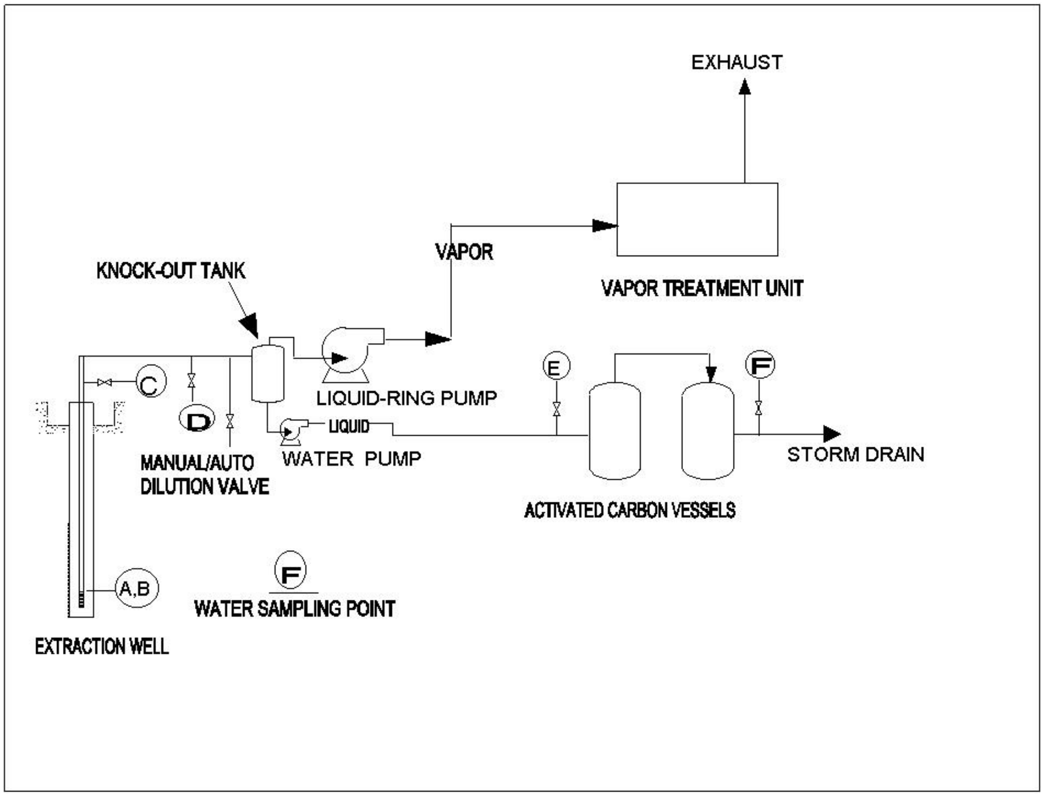

Figure 2. Typical System Schematic: The letter symbols A,B, C, D, E, and F indicates water sample locations.

The stripping tests were performed by collecting water samples from the extraction well, and from the sample ports on extraction stream between the wellhead and the discharge point. The Figure 2 shows the water sample locations (A, B, C, D, E, and F). The sample numbers in tests II through V was changed from the original sample numbers to indicate the location corresponding to the sample locations depicted in Figure 2. The letter A in the sample numbers (MW-13A, BC-6A1, MWS-3A, VW-2A etc.) indicates that the sample was collected before or after the test from the well with a disposable bailer. The letter B indicates that the sample (MW-13B, BC-6B, VW-1B1, MWS-3B, and VW-2B) was collected during extraction with a disposable bailer from the well outside the extraction pipe. The letter C indicates that the sample (MW-13C, BC-6C1, VW-1C, MWS-3C, and VW-2C1) was collected from the sample port at the wellhead. The letter D indicates that the sample (MWS-3D) was collected from the extraction pipe before or from the liquid/vapor separation tank (after 30 to 100 feet of piping run). The letter E indicates that the sample (MW-13E) was collected before the GAC unit, and letter F indicates that the sample (MW-13F) was collected after the GAC unit (discharge sample).

The samples were analyzed by a certified laboratory using EPA Method 8020 and/or 8260, for the volatile hydrocarbons. The results of these analyses were compared to calculate the stripping ratio (difference in concentrations in the well versus extracted water). The stripping ratio, water depth vapor and water flow observed during the tests and applied vacuum were compared to evaluate the factors that affect the striping ratio.

STRIPPING TESTS

Stripping Test I: The first test site is located in Southwest Los Angeles, California. The site, a former gasoline service station, is currently being used as a used car dealership. A Bubblex^{SM} two-phase extraction system was installed using a thermal catalytic oxidizer, a liquid ring pump and two 500-pounds (226.8 kg) GAC units. After operating about a month, a stripping test was performed in two extraction wells (MW-13 and MW-14) to estimate the carbon use. During the stripping test five water samples (MW-13A, B, C, E, and F and MW-14A, B, C, E, and F) were collected from each well. The analytical results of water samples collected during the test are presented in Table 1. Depth to water during stripping test in the extraction wells were 38 feet (11.58 m) below ground surface (bgs). Average vacuum at the wellhead was 108 inches (274 cm) of water column (W.C.). Water flow rate was less than 1-gallons per minute (gpm, 0.06 lt./sec). Vapor flow rate was 190 cubic feet per minute (CFM, 5.38 m^3/min).

A comparative evaluation of the laboratory analyses indicated that: (1) 99% of the benzene, toluene, ethylbenzene, xylene (BTEX), and total petroleum hydrocarbons as gasoline (TPH-G) were removed from the water during extraction inside the Bubblex^{SM} extraction pipe in the wells (between samples B and C). The low concentrations of methyl-tert-butyl-ether (MTBE, 6.5 and 11 micrograms per liter {ug/L]) were reduced below laboratory detection limit of 0.5 ug/L in the extraction well between the water table and the wellhead sampling port “C” (Figure 2, Table 1). Additionally, 99% of the remaining hydrocarbons were removed in the extraction pipe (approximately 100 feet [30 m] long) between the wellhead and carbon unit (between samples C and E). Subsequent NPDES inlet samples (before GAC) verified this test results with hydrocarbon concentrations near or below detection limits for over a year.

TABLE 1. Hydrocarbon concentrations (ug/L) in the extracted water collected during Stripping Test I

Sample No.	Benzene	Toluene	Ethylbenzene	Xylenes	TPH-G	MTBE
MW-13A	6,000.0	8,900.0	5,800.0	21,700.0	180,000.0	5.5
MW-13B	3,800.0	19,100.0	3,400.0	20,700.0	190,000.0	6.1
MW-13C	93.0	250.0	28.0	470.0	2,200.0	0.5
MW-13E	0.4	8.8	3.0	18.0	240.0	0.5
MW-13F	0.1	0.1	0.1	8.0	100.0	0.5
MW-14A	3,000.0	12,800.0	4,100.0	19,400.0	140,000.0	7.6
MW-14B	5,000.0	24,000.0	6,600.0	27,600.0	420,000.0	11.0
MW-14C	170.0	440.0	16.0	820.0	2,200.0	0.5
MW-14E	22.0	42.0	0.8	120.0	1,000.0	0.5
MW-14F	0.2	0.2	0.6	0.9	43.0	0.5

Test II: A stripping test was performed as an add-on to a vapor extraction test at an active gasoline service station in Lawndale, California. Duration of the test was 1/2 hour. A positive displacement blower with 200 inches of W.C. (508 cm) vacuum capacity was used to extract water and vapor. The depth to water in the extraction well was 15 feet bgs (4.57 m). The average water removal rate was 6 gpm (0.38 lt/sec). The average vapor flow rate was 87 CFM (2.46 m^3/min). The water samples were analyzed for BTEX and MTBE, using EPA Method 8020 and 8260 (Table 2). The laboratory results indicated that 80% of the BTEX and 50 % to 60 % of the MTBE were stripped within the extraction pipe section between the water table and the wellhead (Table 2).

TABLE 2. Hydrocarbon concentrations (ug/L) in the extracted water collected during Stripping Test II

Sample No.	B	T	E	X	MTBE(8260)
BC-6A1	2150	4880	1600	8470	12200
BC-6C1	270	5	58.9	328	6000
BC-6B	1470	1780	1230	4580	9700
BC-6C2	117	98	111	498	3960
BC-6C3	135	112	134	580	4070
BC-6A2	886	740	1050	3730	6460

Stripping Test III: The third stripping test was performed using a super sucker (vacuum truck) during weekly LNAPL recovery at a former fuel service station site in Los Angeles, California. The Bubblex^{SM} extraction pipe was placed in the well allowing 3 feet (0.91 m) of water drawdown in the well and extracting water and vapor at the same time. The total duration of the test was ten minutes (the time between the first sample and the last sample). The depth to water in the extraction well was 43 feet (13.11 m) bgs.

The test was performed with 80-inches (203 cm) of W.C. vacuum applied to the wellhead and the Bubblex^SM modified extraction pipe. Estimated vapor flow rate was 50 CFM (1.42 m^3/min) and water flow rate was less than one gpm. Three water samples, two from the well using disposable bailers during extraction and one from the extracted/stripped water at the well-head after 43 feet (13 m) of lifting and stripping, were collected. The water samples were analyzed for BTEX, MTBE, and other oxygenates (TBA, ETBE, TAME) using EPA Method 8260 (Table 3).

The results indicated that 80% of the MTBE was stripped within the 43 feet (13 m) of stripping column in the well.

TABLE 3. Hydrocarbon concentrations (ug/L) in the extracted water collected during Stripping Test III.

Sample No.	B	T	E	X	MTBE	TBA, TAME, ETBE
VW-1B1	2,110.0	290.0	87.0	9,220.0	1,060.0	ND
VW-1C	ND	ND	ND	ND	209.0	ND
VW-1B2	2,030.0	213.0	ND	8,010.0	1,040.0	ND

ND: None Detected

Stripping Test IV: The fourth stripping test was performed using a super sucker (vacuum truck) at an operating fuel service station site in Yorba Linda, California. The depth to water in the extraction well was 34 feet (10.36 m) bgs. The test was performed with 80-inches of water vacuum applied to the wellhead and extraction pipe. Four water samples, two from the well using disposable bailers and two from the extracted/stripped water (one at the wellhead after 34 feet (10.36 m) of lifting and stripping, and one sample (MWS-3D) from the observation/sampling tank at the vacuum truck after 30 feet [10.36 m] of piping/hose run) were collected. The water samples were analyzed for BTEX, MTBE, and other oxygenates (TBA, ETBE, TAME) using EPA Method 8260 (Table 4).

The results indicated that 74% of the MTBE and 40% of BTEX were stripped within the 34 feet of extraction pipe section in the well.

TABLE 4. Hydrocarbon concentrations (ug/L) in the extracted water collected during Stripping Test IV.

Sample No.	B	T	E	X	MTBE	TBA, TAME, ETBE
MWS-3A	3,900	4,200	410	2,000	800,000	ND
MWS-3C	1,900	3,200	250	1,600	71,000	ND
MWS-3D	820	1,300	51	670	56,000	ND
MWS-3B	5,300	4,000	650	2,000	270,000	ND

ND: None Detected

Stripping Test V: The fifth stripping test was performed using a 500 CFM (14.16 m^3/min) capacity catalytic oxidizer with a positive displacement blower capable of 150 in W.C. (381 cm W.C.) at an operating fuel service station site in Antioch, California. The depth to water in the extraction well was 37 feet (11.28 m) bgs. The test was performed with 110-inches of W.C. (279 cm W.C.) vacuum applied to the wellhead and extraction pipe. Vapor flow was 140 CFM (3.96 m^3/min) and the water flow was 0.5 gpm (0.03 lt./sec) during the test. Four water samples, two from the well using disposable bailer and two from the extracted/stripped water at the wellhead after 37 feet (11.28 m) of lifting and stripping were collected. The water samples were analyzed for BTEX and MTBE using EPA Method 8020 (Table 5).

The results indicated that over 99% of the BTEX and 98% of the MTBE were stripped within the 37 feet (11.28 m) of extraction pipe section in the well.

TABLE 5. Hydrocarbon concentrations (ug/L) in the extracted water collected during Stripping Test V.

Sample No.	B	T	E	X	MTBE
VW-2A	15,000	5,500	1,700	9,500	18,000
VW-2C1	14	6.7	ND	36	290
VW-2C2	28	24	1.3	67	300
VW-2B	11,000	4,900	1,300	9,300	15,000

ND: None Detected

SUMMARY

The test results showed that the stripping ratio is higher when (1) the extraction vacuum is higher, (2) water flow rate is lower, (3) vapor flow rate is higher, and (4) groundwater in the extraction well is deeper. It was also observed that BTEX stripping ratio was higher than MTBE stripping ratio with the exception of Test IV at the Yorba Linda Site (Table 6). Although we do not have any clear explanation for this, we think that the high BTEX vapor concentrations drawn into the extraction pipe from the vadose zone prevented further volatilization of the BTEX at the Yorba Linda Site.

CONCLUSION

The authors conclude that Bubblex^{SM} two-phase extraction can be used successfully for stripping VOC from the extracted groundwater. The innovative use of two-phase extraction will eliminate the need for an additional air stripper, and reduce the carbon treatment cost significantly. Additional studies including the vapor concentration and mass balance calculations under a controlled environment will yield valuable information and cost saving alternatives for the clean up of VOC contaminated groundwater.

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TABLE 6. Comparative Evaluation of the Test Parameters

	TEST I Los Angeles	TEST II Lawndale	TEST III Los Angeles	TEST IV Yorba Linda	TEST V Antioch
Depth (ft) to Groundwater	38	15	43	34	37
Extraction Vacuum (inches of W.C.)	108	210	80	80	110
Vapor Flow (CFM)	190	87	~50	~50	140
Water Flow (gpm)	<1.0	6.0	<1.0	1.3	0.5
Average MTBE Stripping Ratio in the well	92%	47%	80%	74%	98%
Average BTEX Stripping Ratio in the well	98%	90%	>99%	40%	>99%

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