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Technical Memorandum

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Subject: **Re-Evaluation of Volatile Organic Compound Treatment**
Dual Site Groundwater Operable Unit
Torrance, California

1. INTRODUCTION

This memorandum was prepared by Geosyntec Consultants (Geosyntec), with assistance from Hargis + Associates (H+A), to advise EPA of the basis and status of an on-going evaluation of the treatment train for volatile organic compounds (VOCs) for the Dual Site Groundwater Operable Unit treatment system (herein referred to as the Torrance Groundwater Remediation System, or "TGRS"). A discussion of the suggested path forward also is provided.

Based on historic data and preliminary engineering analysis conducted several years ago, the primary VOCs expected to be treated by the TGRS are chlorobenzene and benzene. This led to a treatment plan utilizing liquid-phase granular activated carbon (LGAC) as the primary treatment process. However, recent more complete evaluations of groundwater data, performed to predict the start-up chemical profile of the influent groundwater to the TGRS, indicate that several other VOCs with concentrations above in-situ groundwater standards (ISGS)[1] are present in the

[1] An ISGS is defined in the USEPA Record of Decision for the Montrose Chemical Corporation and Del Amo Superfund Sites as the more stringent of the federal and state MCL where these exist. Solely for chemicals with no state or federal MCL promulgated, the ISGS is the EPA May 7, 1998 tap water PRG.

groundwater above ISGSs and will need to be treated. Please refer to the summary of predicted VOC influent concentrations in Table 1 below.

The VOCs listed in Table 1 include many that are quite amenable to treatment with LGAC. However, among the Table 1 VOCs are methylene chloride, chloroform, and 1,2-dichloroethane (1,2-DCA). These three compounds (to be collectively referred to as "secondary VOCs" for the purposes of the memo) are VOCs that are not effectively treated by LGAC and are the subject of this memo.

Table 1
Influent VOC Compilation Summary

Chemical Class	Analyte	Predicted Influent Concentration (µg/L)	Regulatory Concentration (ISGS)[a] (µg/L)
VOC	Benzene	**250**	1
	Chlorobenzene	**13,900**	70
	1,2-Dichloroethane	**9**	0.5
	Tetrachloroethylene	**170**	5
	Trichloroethylene	**38**	5
	1,4-Dichlorobenzene	**17**	5
	Chloroform	**340**	100
	Carbon Tetrachloride	**1.5**	0.5
	1,2,4-Trimethyl Benzene	**11**	12
	Methylene Chloride	**16**	5

[a] ISGS: In-Situ Groundwater Standard

The presence of the secondary VOCs and their recalcitrance to LGAC treatment will result in much higher rates of carbon usage than previously anticipated for the other VOCs. For example, to treat the influent shown in Table 1 with LGAC to meet ISGSs would require approximately 7,500 pounds of carbon per day at initial expected influent concentrations.[2] This is significantly higher than the 300 to 500 pounds per day LGAC usage rates that were formerly estimated by Siemens based on the chlorobenzene and benzene influent concentrations. As a result, the presence of these secondary VOCs will significantly increase carbon changeout frequency when compared with previous estimates of LGAC usage that led to the selection of LGAC. The end

[2] This carbon usage rate was estimated by a carbon supplier, Siemens, which uses an adsorption modeling program to calculate the mass of VOCs that can be adsorbed by a given mass of carbon before the carbon becomes saturated with VOCs to the point where it loses its effectiveness.

result will be greatly increased operating costs, traffic, and carbon handling/scheduling complexities.

Historically, various VOC treatment alternatives in addition to LGAC have been evaluated for use at the TGRS by AECOM (Earth Tech), Geosyntec, and H+A including:

- Air stripping – air stripping was previously considered for VOC treatment but was not selected because of emissions considerations and cost. These drawbacks remain for the treatment of the secondary VOCs.

- Advanced oxidation – advanced oxidation technologies (e.g., the HiPOx™ system) are often used for VOC treatment. These technologies, however, generally are not effective at treating methylene chloride, chloroform, and 1,2-DCA. HiPOx™ will, however, continue to be planned for the TGRS to treat para-chlorobenzene sulfonic acid (pCBSA).

As noted above, none of the treatment alternatives previously evaluated provide a practical treatment method for the secondary VOCs. After the treatment issues associated with the secondary VOCs became apparent, Geosyntec conducted additional research to evaluate other technologies capable of treating the secondary VOCs. This review identified macro-porous polymer extraction (MPPE) as a leading candidate because it is a selective extraction technology with a proven capability to remove both the primary and secondary VOCs present in the TGRS influent.

The remainder of this memo provides a discussion of the MPPE technology and a recommended path forward for a bench-scale study and possibly a pilot-scale study to confirm that MPPE is a viable solution to the treatment needs of the TGRS.

2. INFLUENT CONCENTRATIONS OF SECONDARY VOCS

A key variable affecting the evaluation of VOC treatment options for the TGRS is the expected trend in VOC mass loading to the TGRS system over time. The treatment demands (i.e., LGAC carbon usage rate, MPPE media demand, air stripper sizing, etc.) are based on influent VOC concentrations. Previous modeling results predicted that the overall mass loading of chlorobenzene, benzene, and pCBSA to TGRS would decrease over time as concentrations decrease and the influent flowrate decreases.[3] However, influent concentration trends had not

[3] Concentration decline curves prepared by CH2M Hill, 2008.

been estimated for methylene chloride, chloroform, and 1,2-DCA. Geosyntec evaluated concentration trends for the secondary VOCs to ascertain the potential treatment implications of the secondary VOCs.

2.1 1,2-Dichloroethane

The chemical 1,2-DCA could be present in groundwater either as a previously used additive to leaded gasoline or from the degradation of TCE and PCE. A hydrogeologic analysis was performed to evaluate potential trends for 1,2-DCA. Modeling was conducted by S.S. Papadopulos & Associates, Inc. (SSPA) to estimate the long-term concentration decline trend. The initial 1,2-DCA distribution in the model was based on concentration contours developed using data from 2004 to the present for the principal aquifer units. The distribution in the aquitards was specified using similar assumptions as EPA utilized for modeling chlorobenzene, benzene, and pCBSA. The model utilized the current wellfield configuration.

The model predicted that the influent 1,2-DCA concentration declines rapidly in the initial years of operation (following a trend similar to that of chlorobenzene). While an overall concentration reduction of greater than 90 percent is expected after 7 years, the model simulation indicates that an influent concentration below the ISGS of 0.5 µg/L will not be achieved, even after 30 years of operation. Thus, it is expected that the TGRS will need to treat 1,2-DCA for the duration of the TGRS remedy.

2.2 Chloroform

The dissolved chloroform plume is located near the Montrose property; the highest concentrations are in the Upper Bellflower Aquifer (UBA), with lower concentrations in the Bellflower Sands (BFS). Chloroform is a component of DNAPL and during operation of the TGRS, extraction wells near the Montrose property will operate over the long-term to hydraulically contain the DNAPL-impacted area.

Modeling was not conducted for chloroform because the model is more useful for evaluating reduction over time of a plume that has migrated downgradient rather than evaluating concentrations emanating from a constant source. However, given the expected presence of a continuing DNAPL source, chloroform will persist in the near-property extraction wells. Thus, it is expected that the TGRS will need to treat chloroform for the duration of the remedy.

2.3 Methylene Chloride

Methylene chloride is an intermediate product of the bioremediation of chloroform under anaerobic conditions. Since it is also related to a constant source, as is chloroform, model simulations were not conducted for methylene chloride for the same reasons that modeling was not conducted for chloroform. Given the continuing source of chloroform, it is likely that methylene chloride also will persist in the extraction wells near the Montrose property. Therefore, it is expected that the TGRS will need to treat methylene chloride for the duration of the remedy.

3. PRELIMINARY EVALUATION OF MPPE

As stated in Section 1 of this memo, MPPE was identified as a potential treatment technology to address the need for treatment of secondary VOCs. During initial screening of MPPE, Geosyntec reviewed three critical aspects: 1) previous application experience with the technology at other sites; 2) the overall probability of successful treatment of the primary and secondary VOCs within the TGRS influent groundwater matrix; and 3) and the long-term stability in supply of the MPPE material.

3.1 MPPE Technology Application

Table 2 contains a representative listing of sites where MPPE has been used to treat groundwater. MPPE is also used to treat process water and wastewater, including for petroleum refineries and power plants. In California, the MPPE technology was used to treat chlorinated solvents (primarily PCE) in groundwater during a pilot test at the Former Naval Air Station in Alameda. The MPPE treatment system was used to remove PCE and ethanol from over 170,000 gallons of aqueous liquid that was extracted directly from the dense non-aqueous phase liquid (DNAPL) source zone. The Alameda pilot test was not carried forward to full scale because the cleanup objectives for the site were met during the pilot test and treatment was discontinued.

MPPE also has been bench-tested as a potential groundwater treatment technology by a major aerospace manufacturer at a southern California facility. It is our understanding that a different technology recently was selected for that project due to cost considerations resulting from the specific chemicals being treated.

Table 2: Summary of MPPE Groundwater Case Studies

Location	Client Site	Flow Rate (gpm)	Target Compounds	Influent Concentration mg/L (ppm)	Effluent Concentration mg/L (ppm)
Alameda, California	Former Naval Air Station	NA	Chlor. Solvents	200	>99% removal of Chlor. Solvents
LeMoyne, Alabama, USA	Akzo Nobel Chemicals	44	Chlor. Solvents	30	<0.2
Lenoir, North Carolina, USA	Akzo Nobel Coating	4.4	BTEX	100	<0.005
Hartwell, Georgia, USA	Tenneco Automotive	5	Chlor. Solvents	8.8	> 99% removal
Rotterdam, The Netherlands	LBC,Groupe Fimalac	66/0.44	Chlor. Solvents	5/2000	<0.1
Oss, The Netherlands	Diosynth	176	Al, BTEX, Chlor. Solvents	600	<1
Amsterdam, The Netherlands	Solvay Pharmaceuticals	154	Chlor. Solvents	100	<0.01
Mannheim, Germany	Zurich Insurances, Site Akzo Nobel Chemicals	79.2	Chlor. Solvents	5	<0.006
Flensburg, Germany	Stadtwerke Flensburg GmbH	26.4	BTEX, PAH	14	<0.01
Ruhr, Germany	Chemical Manufacturer	528	Chlor. Solvents, BTEX	0.6	<0.01
Cologne, Germany	Chemical Manufacturer	220	Chlor. Solvents	13.8	<0.1
Castrop Rauxel, Germany	Alsco	66	DNAPL, Chlor. Solvents	Hundreds	> 99% removal
Schwarze Pumpe, Germany	LMBV HB 21n	26.4, 44, 88	BTEX, PAH	50 – 150	> 95% removal
Lauchammer, Germany	LMBV HB 96n	13.2	BTEX, PAH	140	> 99.9% removal
Dortmund, Germany	Shell	15.4	TPH (1.16 mg/L @91% removal); BTEX + TMB (965 µg/L@99.5% removal); MTBE (384 µg/L @99.2% removal); PAH's (28.7 µg/L @96% removal)		
Calais, France	Sythexim	26.4	BTEX, Chlor. Solvents, COD	1100 – 1400	> 99.9% removal
France	Water Service Company	8.8	Chlor. Solvents, BTEX	700	< 0.5
Libya	Brega	88	Gasoline, Diesel	1000	>99% removal

Source: Whittier Filtration Marketing Literature; www.whittierfiltration.com, and Geosyntec Consultants project experience.

Abbreviations

Al = Aliphatics
PAH = Polycyclic Aromatic
BTEX = Benzene, Toluene, Ethylbenzene, Xylenes
DNAPL = Dense Non Aqueous Phase Liquids
Chlor. Solvents = Chlorinated Solvents
NA – Not Available

3.2 Application to TGRS Influent Groundwater

Based on reviews of available case studies and Veolia product literature, MPPE appears to be capable of treating water to remove VOCs. However, testing of the technology will be conducted to confirm that it will be effective at treating the constituents in TGRS groundwater (see Section 4). If the results of the testing indicate that MPPE successfully removes primary and secondary VOCs present in TGRS influent cost-effectively, then MPPE can be integrated into the treatment plant in one of two ways: full-stream treatment or side-stream treatment.

Full-stream treatment would include treatment of the full 700 gpm TGRS groundwater influent through the MPPE unit to remove primary and secondary VOCs. Depending on testing results, the water would need no further treatment other than advanced oxidation for pCBSA treatment.

Under the side-stream treatment scenario, a 380 gpm side stream of water from extraction wells expected to contain primary VOCs and elevated concentrations of secondary VOCs would be treated by MPPE. Side-stream treatment by MPPE includes groundwater from the following wells: **MBFB-EW-1**, UBA-EW-1, **UBA-EW-2**, BF-EW-1, BF-EW-4, BF-EW-5, BF-EW-6, G-EW-1 (**bold** denotes two wells which already will be piped to the treatment plant separately for possible arsenic treatment). These wells were selected because they would result in a side-stream with elevated concentrations of secondary VOCs for MPPE treatment. The added consideration is additional capital cost for pipelines and system controls to deliver influent from these wells separately. The effluent from side-stream MPPE treatment would join with the remaining groundwater influent prior to HiPOx™ treatment for pCBSA. Following HiPOx™ treatment, the 700 gpm flow would proceed to an LGAC unit to treat the remaining VOCs in the 320 gpm stream that was not part of the side-stream. This approach may result in an overall lower system cost than full-stream treatment.

The predicted flowrates and influent concentrations for secondary VOCs given the two treatment scenarios are summarized in the following table:

	ISGS	Full-Stream Treatment	Side-Stream Treatment	
			MPPE Treatment	Other Wells
Flow Rate	N/A	700 gpm	379 gpm	322 gpm
1,2-DCA	0.5 µg/L	9 µg/L	8 µg/L	10 µg/L
Methylene Chloride	5 µg/L	16 µg/L	27.7 µg/L	2.2 µg/L
Chloroform	100 µg/L	340 µg/L	622 µg/L	ND < 40 µg/L

MPPE capital costs generally are higher than for LGAC and/or air stripping technologies, but annual costs tend to be significantly less during the early years of operation when concentrations are expected to be the highest. Given the fact that MPPE is a technology based on liquid-liquid partitioning (rather than mixing of reagants), the ability of MPPE to treat secondary VOCs over time is not expected to diminish as concentrations decline. Additionally, evaluations to date suggest that MPPE is compatible with advanced oxidation treatment, and the sequence of operation is ultimately dependant on treatment considerations (i.e., waste generation rates, cost, etc.).

3.3 Stability of Long-Term Supply

Geosyntec considered the viability of the MPPE treatment for the operating lifetime of the TGRS. Two issues are relevant: the viability of the business unit and the viability of the technology. Regarding viability of the business unit, we note that *Veolia Environment North America* (Chicago, IL), is ranked second in the current Engineering News-Record list of top 200 environmental firms.[4] The firm's market position is evidently quite strong, and there is reason to believe that this business unit will be viable for the foreseeable future.

Regarding viability of the technology, the MPPE technology has been used for approximately 15 years at numerous sites worldwide. The technology may evolve over time, as is the case with similar technologies such as carbon treatment technology. However, the combination of Veolia's solid market position and the relative attractiveness of the technology for the stated application serve to reinforce the likely durability of the technology, in either its present form or in evolved forms, for continued use in the TGRS, whether it is provided by Veolia or by a competitor.

4. PATH FORWARD

To evaluate the effectiveness of MPPE to treat both primary and secondary VOCs in TGRS influent, a bench-scale test is planned. If successful, the bench-scale test would be followed by a pilot-scale test program. MPPE bench testing will require approximately five weeks, including coordination with EPA, analytical data turnaround times, and data analysis/reporting.

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[4] Engineering News-Record. August 3, 2009.

4.1 Bench-Scale Test

MPPE bench-scale testing will consist of "shaker testing" and "column testing" to be conducted by Whittier Filtration, a division of Veolia. To conduct the test, Geosyntec will collect one bulk sample from two groundwater wells (MBFB-EW-1 and BF-EW-1: see Section 4.2 for the well selection process) to approximate the expected start-up influent concentrations. The sample will be sent to the Whittier Filtration lab located in Plainfield, Illinois.

During the shaker testing, varying amounts MPPE media will be added to a known volume of influent water. The MPPE media and water will be allowed to remain in contact for a specific period of time. Initial and final concentrations will be measured from each sample to calculate the mass of VOCs extracted per mass of media.

During the column testing, water will be run at a constant flow rate through a standard-sized column packed with MPPE media. The column effluent water will be sampled and analyzed to calculate the breakthrough characteristics of both primary and secondary VOCs. The results of the column test will demonstrate whether MPPE can treat the VOCs consistently to concentrations below ISGSs and will allow for development of cost estimate projections.

The bench-testing data thus will be analyzed to understand if MPPE is a viable and cost-effective technology for the TGRS and to decide whether to proceed with a pilot test.

4.2 Source Water for Bench-Scale Testing

In general, the source wells used for the bench-scale test need to provide representative concentrations of the secondary VOCs and be accessible for sampling, equipment staging, and other logistical issues. Two general criteria were used to select the test source water wells, including:

1. Concentrations of the secondary VOCs that are at or above the following estimated influent concentration to TGRS:
   - Methylene chloride – 16 µg/L (full-stream); 28 µg/L (side-stream);
   - Chloroform – 336 µg/L (full-stream); 622 µg/L (side-stream); and
   - 1,2-DCA – 9 µg/L (full-stream); 8 µg/L (side-stream).

2. Concentrations of the other major chemicals of concern that are at or above the following estimated influent concentration to TGRS:

   - Chlorobenzene – 13,900 µg/L (full-stream); 19,160 µg/L (side-stream); and
   - pCBSA –39,630 µg/L (full-stream); 28,140 µg/L (side-stream).

In addition, there is a preference for contingent pilot-testing to be conducted on wells that are not located in the residential areas of the treatment system, because of the potential for minor disruption of the community during testing. The selection criteria narrowed the potential test source wells to a cluster that includes wells MBFB-EW-1, BF-EW-1, and G-EW-1. No single well in this cluster provides concentrations that meet Criteria #1 and #2. Therefore, a number of "blends" were evaluated. Based on this evaluation, it is currently anticipated that a blend of water consisting of approximately 5 percent MBFB-EW-1 and 95 percent BF-EW-1 will be utilized. For contingent pilot testing, these wells also would provide for testing outside of the residential areas of the treatment system. A summary of concentration data from a weighted average of **5 percent MBFB-EW-1 and 95 percent BF-EW-1** is shown in the following table:

Analyte	**Units**	**Target TGRS Influent Concentration**		**Approx Conc. From a Blend of Source Wells MBFB-EW-1 and BF-EW-1**
		Full-Stream Scenario	**Side-stream Scenario**	
Total VOCs	µg/L	**14,900**	**21,000**	**38,500**
1,2-Dichloroethane	µg/L	**9**	**8**	**23**
Benzene	µg/L	**250**	**450**	**1030**
Carbon Tetrachloride	µg/L	**1.5**	**2.9**	**< 0.5**
Chlorobenzene	µg/L	**13,900**	**19,160**	**35,200**
Chloroform	µg/L	**340**	**620**	**1,700**
Methylene Chloride	µg/L	**16**	**28**	**35**
Tetrachloroethylene	µg/L	**170**	**290**	**60**
Trichloroethylene	µg/L	**38**	**69**	**53.5**
pCBSA	µg/L	**39,600**	**28,100**	**53,800**

Given the complex distribution of chemicals in the groundwater, it is not possible to replicate exactly the projected influent concentrations. However, as shown in the table above, the selection criteria are expected to yield a mixture that is useful for the purposes of this bench test.

Whittier Filtration has reviewed the approach discussed above and determined that it is acceptable to test water with VOC concentrations above expected full-scale influent concentrations. Test results will demonstrate whether the technology is effective and will also allow Whittier Filtration to generate partitioning coefficients that can be used to predict removal efficiencies for a specified set of influent concentrations. Thus, Whittier Filtration has confirmed that the elevated concentrations in the source wells will lead to useful and appropriate design information.

4.3 Pilot-Scale Testing

If the bench-scale test is successful, a pilot-scale test will be conducted to evaluate the effectiveness of the technology to treat both primary and secondary VOCs in the field. As soon as feasible upon the availability of the bench-scale test results, a workplan will be developed for the pilot scale test for review by EPA. Current estimates are that pilot-scale testing would take approximately 11 weeks, including coordination with EPA, two weeks of testing, analytical data turnaround times, and data analysis/reporting. The schedule assumes that no delays will be experienced due to pilot-scale unit availability, permitting requirements, or access delays

5. VOC TREATMENT SELECTION

Following completion of testing, Montrose will complete the re-evaluation of VOC treatment approaches and make a final recommendation to EPA on the preferred approach. The selected approach will be incorporated into the design of the treatment plant.