SRSNE Site Group

Remedial Design Work Plan Attachment D

Vapor Treatment Needs Evaluation Work Plan

Solvents Recovery Service of New England, Inc.
(SRSNE) Superfund Site
Southington, Connecticut

November 2010

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Attachment D

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SRSNE Site Group

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Executive Summary

The Vapor Treatment Needs Evaluation Work Plan was prepared to address Section V.C.1.d of the Statement of Work (SOW), which states that an evaluation of vapor treatment needs and options may be conducted to evaluate vapor treatment design options, including bench scale testing if necessary. At this time, it is believed that bench-scale testing will not be required as the vapor treatment components contemplated for the Site are all commercially available and in widespread use for similar applications.

The focus of this Work Plan is the integration of these commercially available components into a system that achieves the following objectives:

- Successfully treat the range of Site constituents of concern (COCs) and maintain compliance with the specified discharge limits;
- Maintain operational performance in response to changing COC composition, mass loading, and extraction rates, without impeding the progress of the heating operation; and,
- Incorporate sufficient flexibility to allow for scale-up/scale-down of operations in response to changing COC mass loading and extraction rates to optimize energy efficiency of the selected vapor treatment system.

Vapor Treatment System Performance Testing and Permit Compliance

Since the remediation is being performed as part of a Superfund remediation action, a Connecticut Department of Environmental Protection (CTDEP) air permit is not required. However, in accordance with CTDEP, the proposed vapor phase control system will be designed to meet or exceed Best Available Control Technology (BACT) criteria, which will demonstrate compliance with applicable requirements, including but not limited to the following:

- Emissions calculations, including Hazardous Air Pollutant (HAP) Maximum Allowable Stack Concentrations (MASC) compliance analysis;
- BACT Analysis using EPA/NESCAUM “top-down” procedures; and,
- Program for compliance demonstration.

In addition, potential emissions after control are expected to be less than major source thresholds. Therefore, Prevention of Significant Deterioration (PSD) and non-attainment New Source Review (NSR) requirements will not apply and the facility should not be considered a major source of HAPs.

Design Basis

Several input parameters will be evaluated as Applicable or Relevant or Appropriate Requirements (ARAR) and incorporated into the vapor treatment system final design. A comprehensive list of these parameters can be found in the document as Tables D-1 through D-3.

Some conceptual design and evaluation work on the vapor treatment system for the Site was performed during preparation of the Technical Proposal. The conceptual screening analysis evaluates each alternative's ability to achieve the project requirements of adequate treatment, scalability, capability to handle the anticipated VOC loading conditions, and expected reliability. The following technologies have been evaluated and their ability to achieve the project requirements is discussed below:

- **Vapor Phase Carbon, Sacrificial and On-Site Steam Regeneration:** Both vapor phase carbon technologies use activated carbon granules. Volatile organic compounds (VOCs) are sorbed on to the carbon pore space surface. Neither of these technologies is practical for use as the primary treatment means for approximately 1 million pounds of non-aqueous phase liquid (NAPL).

- **Solvent Recovery by Condensing:** Solvent recovery by condensing lowers the temperature of the vapors to reduce the vapor pressures of each of the VOCs. The individual VOCs begin to condense as their partial pressures diminish with cooler temperatures. A number of the selected Site COCs have vapor pressures above that of water, which results in needing colder temperatures before chilling/condensing will occur. Additionally, several COCs are high-vapor pressure compounds, which are resistant to condensing.

  Solvent recovery with reduced temperatures can be enhanced at elevated pressures. This occurs because the partial pressures of the VOCs increase with increasing pressure, which, in turn, reduces the

relative concentration of each individual constituent. However, condensing the VOCs will generate a large liquid waste stream that would require off-site disposal.

This potential waste disposal issue, coupled with the fact that some of the primary Site COCs are not easily removed by condensing, make this option less attractive as a primary treatment alternative.

- **Thermal Oxidation:** Thermal oxidization exposes the vapors to temperatures well above the autoignition temperature of the VOCs. A surplus of oxygen is required for complete combustion and provisions are required to dissipate the large amount of thermal energy released during combustion of the VOCs. The combustion of Chlorinated VOCs (CVOCs) will produce hydrogen chloride gas and as such, the oxidizer exhaust vapors will require further treatment by scrubbing with a caustic soda solution to neutralize the acid gas vapors, prior to discharge to the atmosphere. The product of this neutralization is salt.

  Given the highly concentrated and variable nature of the Site COCs, it is anticipated thermal oxidation will be the most robust and capable primary vapor treatment technology for this Site.

- **Combined Condensing & Thermal Oxidation:** In this option, condensing through cooling or compression and cooling is used as a pre-conditioning step prior to thermal oxidation. The benefits of such a combined system utilizing different vapor treatment technologies will enhance the operational flexibility to handle a potentially changing vapor composition over time. Further, a combined system may also improve robustness and reliability, in that if one system or component must be temporarily shut down for maintenance, the other system is available to continue treating the extracted vapors.

Vapor Treatment Alternatives for Further Consideration

At this time, thermal oxidation has emerged as the preferred vapor treatment alternative, either alone or in combination with other technologies that may include front-end condensing for resource recovery or peak load management, or vapor phase carbon for final effluent polishing. Initial consultations with several oxidizer vendors indicate that the anticipated peak

mass load may require the use of substantially oversized oxidizers, with a significant amount of dilution air introduced, which would result in a significant increase in both capital and operating costs. Further evaluations with this technology will be performed. The final system design will be based on the results of this evaluation.

1. Purpose and Scope

This document has been prepared on behalf of the SRSNE Site Group, an unincorporated association of Settling Defendants to a Consent Decree (CD) and Statement of Work (SOW) for the Remedial Design/Remedial Action (RD/RA) at the Solvents Recovery Service of New England, Inc. (SRSNE) Superfund Site in Southington, Connecticut (Site). The CD was lodged on October 30, 2008 with the United States District Court for the District of Connecticut in connection with Civil Actions No. 3:08cv1509 (SRU) and No. 3:08cv1504 (WWE). The CD was entered by the Court on March 26, 2009.

Section V.C.1 of the SOW suggests that certain pre-design studies may be undertaken prior to the design and implementation of the remedy for the Site. Specifically, Section V.C.1.d of the SOW states that an evaluation of vapor treatment needs and options may be conducted to evaluate vapor treatment design options, including bench scale testing if necessary. At this time, it is believed that bench-scale testing will not be required as the vapor treatment components contemplated for the SRSNE Site are all commercially available and in widespread use for similar applications.

The challenge for this site and the focus of the "Vapor Treatment Needs and Options Evaluation" described in this Work Plan is the integration of these commercially available components into a system that achieves the following objectives:

- Successfully treat the range of Site constituents of concern (COCs) and maintain compliance with the specified discharge limits;

- Maintain operational performance in response to changing COC composition, mass loading, and extraction rates, without impeding the progress of the heating operation; and

- Incorporate sufficient flexibility to allow for scale-up/scale-down of operations in response to changing COC mass loading and extraction rates to optimize energy efficiency of the selected vapor treatment system.

With those objectives in mind, the “Vapor Treatment Needs and Options Evaluation” will evaluate commercially available and proven vapor treatment technologies suitable for treating both the range and anticipated mass load of the SRSNE Site COCs.

Some preliminary evaluations and conceptualizations have been developed in the course of preparing the technical proposal for this project and in developing this Work Plan. The Vapor Treatment Needs and Options Evaluation will start from the preliminary concept basis described in this Work Plan. Specific vapor treatment scenarios will be developed and evaluated for use during thermal remediation at the SRSNE site. Conclusions from the Vapor Treatment Evaluation will serve as the Preliminary Design criteria for the vapor treatment system that will be specified in the Preliminary Design submittal. It is anticipated that the results of the Vapor Treatment Evaluation will be summarized in memo form and presented to the Agencies in an interactive meeting, early in the Preliminary Design development process. Because of the flexibility required, it is possible that a combination of several vapor treatment technologies will be used to treat the extracted vapors.

2. Vapor Treatment System Performance Testing and Permit Compliance

Air pollution control requirements for ISTD are the "Applicable or relevant or appropriate requirements" (ARARs) presented in Table 4-32 of the Feasibility Study (BBL and United States Environmental Protection Agency [USEPA] 2005), and incorporated as Appendix D of the Record of Decision (ROD; USEPA 2005). These ARARs will be reviewed to evaluate and select potential emission limits and compliance monitoring requirements for the recommended vapor treatment alternative. Within this section of the Vapor Treatment Needs and Options Evaluation, the following items will be considered.

- Identification of Applicable Regulations (ARARs)
- Anticipated Permit Equivalency Requirements
- Expected Performance Goals
- Monitoring and Testing Methods
- Daily Monitoring
- Periodic Analytical Sampling
- Methods
- Frequency

Based on the estimated potential vapor-phase flows and pollutant concentrations from the thermal conduction heating (TCH) process, a permit to construct and operate a stationary source of air pollution would normally be required from the Connecticut Department of Environmental Protection (CTDEP) prior to construction. The potential need for an air permit in this case is based on the assumption that stationary sources subject to an air permit to construct and operate must demonstrate compliance with applicable emission limitations, standards and other requirements. Potential requirements applicable to In Situ Thermal Desorption (ISTD) processes include demonstration that Best Available Control Technology (BACT) or Lowest Achievable Emission Rates (LAER) will be employed, that emissions of hazardous air pollutants (HAPs) comply with applicable Maximum Allowable Stack Concentrations (MASCs), and that other monitoring, recordkeeping and operating procedures will be followed.

The proposed vapor phase control system will be designed to meet or exceed BACT criteria. In addition, potential emissions after control are expected to be less than major source thresholds. Therefore, Prevention of Significant Deterioration (PSD) and non-attainment New Source Review (NSR) requirements will not apply and the facility should not be considered a major source of HAPs.

However, because the project is being performed as part of a Superfund remedial action, it is exempt from having to obtain state and local permits such as a CTDEP air permit. Nevertheless, information and analyses will be provided that satisfy the intent of the CTDEP air permitting program and demonstrate compliance with applicable requirements, including but not limited to the following:

- Emissions calculations, including Hazardous Air Pollutant MASC compliance analysis;
- BACT Analysis using EPA/NESCAUM “top-down” procedures; and
- Program for compliance demonstration.

The anticipated permit equivalency requirements and emission monitoring requirements will be integrated into the design submittals, as well as the Operation, Maintenance and Monitoring Plan that will be developed for the site prior to the start of system operation. Treatment equipment specifications provided to vendors will include these anticipated performance requirements, and the system Design will integrate the necessary provisions for the anticipated monitoring requirements.

3. Design Basis

Once the ARAR emission criteria have been identified, the next step in completing the Vapor Treatment Needs and Options Evaluation is to establish the basis of design for the vapor treatment system. This will serve to establish input parameters upon which the Evaluation and the subsequent design of the vapor treatment system will be based, and will ultimately drive the layout and selection of the vapor treatment train. Important components of the basis of design include:

- Total anticipated COC mass load expected to be extracted – presently estimated at 500,000 to 2,000,000 pounds;
- Composition – see Table D-1;
- Heating value [British Thermal Unit/pound (BTU/lb)] of the anticipated mixture = to be established through laboratory analysis of Site dense non-aqueous phase liquid (DNAPL) samples;
- Duration of heating and extraction – 120 to 180 days;
- Expected “average” and “peak” loading conditions – see Tables D-2 and D-3;
- Expected extraction temperatures and pressures;
- Vapor treatment system performance requirements (permit equivalency ARAR discharge limits);
- System redundancy requirements; and
- Other related factors or limitations, including;
- Utility supply requirements and limitations;
- Potable water usage, if any;
- Waste handling/disposal;
- Sewer/storm drain discharge limits;
- Noise limitations;
- Material of construction requirements/limitations for the treatment equipment; and
- Commercial availability.

The basis of design established in the Vapor Treatment System Needs Evaluation and will carry through to the Preliminary Design submittal, where the Process Flow Diagram (PFD), and preliminary Material and Energy Balance will be further developed.

Table D-1. Composition of Chemicals in Thermal Treatment Zone

	VOC Composition, on Average, as % of Total
	Average Composition
Vinyl Chloride	1.4%
1,1-Dichloroethylene	0.1%
Methylene Chloride	0.2%
1,1-Dichloroethane	0.6%
cis-1,2-Dichloroethylene	8.7%
Chloroform	0.0%
2-Butanone	0.3%
1,1,1-Trichloroethane	6.8%
Benzene	0.0%
1,2-Dichloroethane	0.0%
Trichloroethylene	43.4%
4-Methyl-2-pentanone (MIBK)	0.4%
2-Hexanone	0.0%
Toluene	15.0%
1,1,2-Trichloroethane	0.0%
Tetrachloroethylene	13.2%
Ethylbenzene	2.9%
P/M Xylenes	5.1%
O Xylene	2.0%
Styrene	0.2%
TOTAL VOCs	100.4%

Table D-2. Preliminary estimates of mass removal rates during thermal remediation for various mass estimates

		120 days at 100 C					
	heating	production	production	production	production	cooling	
Timeline	Day 1 -30	Days 31 - 60	Days 61 - 90	Days 91 - 120	Days 121 - 150	Days 151 - 180	total
Percent of Total Mass Removed per 30 day period	2.5%	25.0%	30.0%	25.0%	15.0%	2.5%	100%
Mass Scenario (total pounds VOCs, @ 100% removed)	VOC Mass (pounds) per day						
500,000	417	4,167	5,000	4,167	2,500	417	
1,000,000	833	8,333	10,000	8,333	5,000	833	
2,000,000	1,667	16,667	20,000	16,667	10,000	1,667	

Table D-3. Compound specific estimates of mass removal rates during thermal remediation for various mass estimates

	VOC Composition, on Average, as % of Total	Pounds per Day, per VOC, Total Mass Scenarios		
	Average Composition	500,000	1,000,000	2,000,000
Vinyl Chloride	1.4%	69	139	278
1,1-Dichloroethylene	0.1%	6	13	25
Methylene Chloride	0.2%	8	16	31
1,1-Dichloroethane	0.6%	31	62	125
cis-1,2-Dichloroethylene	8.7%	435	870	1,740
Chloroform	0.0%	0	0	0
2-Butanone	0.3%	13	26	53
1,1,1-Trichloroethane	6.8%	338	677	1,354
Benzene	0.0%	1	2	5
1,2-Dichloroethane	0.0%	0	0	0
Trichloroethylene	43.4%	2,171	4,341	8,682
4-Methyl-2-pentanone (MIBK)	0.4%	21	41	83
2-Hexanone	0.0%	0	0	0
Toluene	15.0%	748	1,497	2,993
1,1,2-Trichloroethane	0.0%	0	0	0
Tetrachloroethylene	13.2%	660	1,321	2,642
Ethylbenzene	2.9%	145	290	580
P/M Xylenes	5.1%	256	513	1,026
O Xylene	2.0%	102	204	408
Styrene	0.2%	11	23	45
TOTAL VOCs	100.4%	5,018	10,035	20,070

4. Conceptual Vapor Treatment Alternative Screening Evaluation

As mentioned earlier in this Work Plan, some conceptual design and evaluation work on the vapor treatment system for the SRSNE thermal remediation project was performed during preparation of the Technical Proposal. This section summarizes the vapor treatment technologies that have been considered and the results of the initial concept level technology screening that has been completed to date.

The evaluation of treatment technologies for the SRSNE thermal remediation project is a complex process given the expected large amount of volatile organic compound (VOC) mass to be treated in a relatively short time period, the number of different VOCs making up the total mass to be treated, and the number of variables associated with each of the potential treatment technologies. The ISTD heating process volatilizes nearly all of the VOC mass, so that it is removed from the subsurface almost exclusively in the vapor phase.

An initial screening of commercially available vapor treatment alternatives is presented in the following sections to evaluate the various potential alternatives' capabilities to meet the project's anticipated requirements.

The conceptual screening analysis presented in the paragraphs below evaluates each alternative's ability to achieve the project requirements of adequate treatment, scalability, capability to handle the anticipated VOC loading conditions, and expected reliability. The Vapor Treatment Needs and Options Evaluation will examine the remaining alternatives emerging from this initial screening in more detail, including such additional factors as capital and operating costs as well as utility demands to select the vapor treatment system that will be included in the Preliminary and Final Design submittals.

4.1 Conceptual Vapor Treatment Alternatives

Several vapor treatment alternatives have been considered in a concept-level screening review for the SRSNE Site, as part of this Work Plan. The preliminary alternatives include the following:

- Vapor Phase Carbon, Sacrificial

- Vapor phase carbon, On-site Steam Regeneration
- Solvent Recovery (Condensing)
- Thermal Oxidation
- Combined Condensing & Carbon
- Combined Condensing & Thermal Oxidation
- Following is a brief summary of each preliminary vapor treatment alternative.

4.1.1 Vapor Phase Carbon, Sacrificial

Activated carbon adsorption entails sorption of the extracted VOCs onto the carbon particles pore-space surfaces using a combination of physical and chemical adsorption processes. Each activated carbon granule or pellet consists of micro-porous particles with very large internal surface area. It has been reported that a pound of highly activated carbon has an equivalent surface area approaching 140 acres.

Under the sacrificial carbon alternative, spent activated carbon would be manifested and transported off site for recycling or disposal. Exclusively using activated carbon adsorption for treatment of 1 million or more pounds of VOCs is not practical. Even at an optimistic adsorption capacity of 20%, this project would require in excess of 5 million pounds of activated carbon. Also important is the fact that several of the target VOCs, including methylene chloride and vinyl chloride do not sorb well to activated carbon and thus would not be adequately removed by this treatment technology. However, this alternative will be retained, as it may be useful in combination with another alternative, or as a final polishing step.

4.1.2 Vapor Phase Carbon, On-site Steam Regeneration

Vapor phase carbon with on-site steam regeneration utilizes the same VOC removal mechanism as does sacrificial activated carbon; however, rather than shipping the carbon off-site for disposal, the spent carbon is regenerated utilizing an on-site steam source. This technology is subject to the same

limitations as sacrificial carbon, in that several of the site constituents are not removed by activated carbon. Implementation of this type of system would entail the use of activated carbon media beds constructed as pressure vessels and an on-site steam boiler. On a pre-determined schedule, or as indicated by vessel effluent VOC concentrations, individual beds are isolated from the extracted vapor stream and heated and pressurized with steam over a period of several hours to desorb the VOCs from the carbon particles. Air is then swept through the heated bed to remove the VOCs and cool and dry the media.

The desorbed VOCs and steam are then typically condensed and separated with the VOCs containerized for disposal. This process requires several hours to heat, desorb and cool the beds; therefore, multiple media beds of adequate size will be required to implement this approach. Regeneration control may be either manual or automated; however, given the large VOC mass at this site, regeneration will be frequent and it is expected that the regeneration controls would be automated. After repetitive steam regeneration cycles, the VOC adsorption capacity of the carbon diminishes and the spent carbon requires replacement. Manufacturer advice and observation of carbon performance determines when it is appropriate to replace the spent carbon.

Again, given this technique's limitations with regard to certain VOCs present at this site, this alternative would have to be combined with a secondary VOC treatment technique or be utilized as a final polishing step.

4.1.3 Solvent Recovery (Condensing)

Cooling/condensing solvent recovery systems lower the temperature of the vapors to reduce the vapor pressures of each of the VOCs. The individual VOCs begin to condense as their partial pressures diminish with cooler temperatures. A common analogy to such a system is the removal of water vapor as condensation in a home or office air conditioning system. VOCs recovered as liquid using the cooling/condensing technology will need to be shipped to a licensed facility for destruction or possible recycling.

Figure 1 presents a graph of the vapor pressure versus temperature for 13 site COCs and water. As can be observed from the graph, a number of the selected site COCs have vapor pressure above that of water, whiles others such as perchlorethylene (PCE), methyl isobutyl ketone (MIBK), ethylbenzene,

xylene and styrene have vapor pressures at or below that of water. The range of vapor pressures varies by a factor of 5,000 between vinyl chloride and xylenes. The higher the vapor pressure, the colder it must to be to begin solvent recovery by chilling/condensing for that VOC.

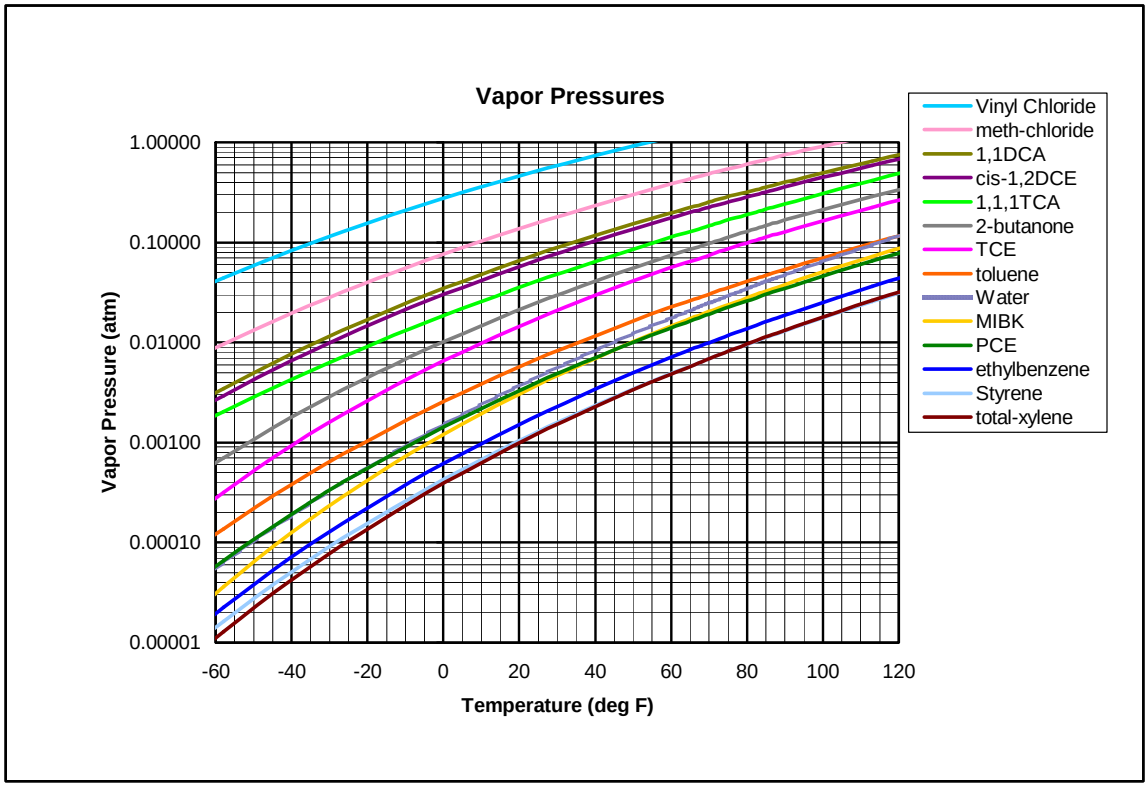

Figure D-1. Graph of the Vapor Pressure Versus Temperature for 13 Site COCs and Water

Of the 13 COC compounds and water represented in the graph above, both cis-1,2 dichloroethene (DCE) and 1,1,1-trichloroethane (TCA) represent particular concern for removal by condensing. Based on a preliminary review of the site COC data, it is believed that together, these two compounds could represent over 10% of the VOC mass at the Site. 1,1,1-TCA is a compound that readily hydrolyzes at temperatures above 50^{o}C, and the rate of hydrolysis increases by approximately one order of magnitude with each 20 degree F increase in temperature. Thus, 1,1,1-TCA may not represent as significant of a vapor phase load on the treatment system, once the subsurface temperature

begins to increase. However, the resistance of cis-1,2-DCE and, to a lesser degree 1,1,1-TCA (prior to the onset of significant hydrolysis), to condensation is a significant consideration in the evaluation of this vapor treatment alternative. Other high-vapor pressure compounds, including vinyl chloride and methylene chloride, which are also present at the site, albeit at lesser concentrations, are resistant to condensing and further, do not sorb well to activated carbon and thus must be given special consideration.

Importantly, the relatively high vapor pressure of these compounds means that they will have to be cooled well below zero (0˚F), likely to the range of -40˚F, to initiate significant condensation. This impacts the type of cooling equipment that will be required to achieve this level of cooling, representing both significant capital and operating costs. Insufficient cooling of these compounds will represent a significant mass of VOCs that will remain in the vapor phase and require further treatment to ensure compliance with emission limits.

Solvent recovery with reduced temperatures can be enhanced at elevated pressures. This occurs because the partial pressures of the VOCs increase with increasing pressure, which, in turn, reduces the relative concentration of each individual constituent. For example, compressing the vapors to 3 atmospheres absolute [~45 pounds per square inch, gauge (psig)] will reduce the condensation concentration by a factor of 3. Likewise, compressing the vapors to 10 atmospheres absolute (~150 psig) will reduce the condensation concentration by a factor of 10. Thus, by adding a compressing step in conjunction with the cooling process, a proportionately larger volume of contaminant can be condensed at a given temperature.

Condensing the COCs will generate a liquid waste stream. It is possible that there may be a recycling avenue for some or all of the recovered liquids; however, most likely the recovered liquid NAPL will have to be manifested off-site for disposal. Thus, the estimated mass of 500,000 to 2,000,000 pounds of NAPL could generate on the order of 50,000 to 200,000 gallons of liquid waste requiring off-site disposal.

This potential waste disposal issue, coupled with the fact that some of the primary site COCs are not easily removed by condensing, make this option less attractive as a primary treatment alternative. However, the condensing option will be retained for potential consideration in the Vapor Treatment Needs and Options Evaluation as a pre-treatment or peak-leveling alternative.

4.1.4 Thermal Oxidation

Thermal oxidization systems expose the vapors to temperatures well above the autoignition temperature of the VOCs. A surplus of oxygen is required for complete combustion and provisions are required to dissipate the large amount of thermal energy released during combustion of the VOCs. The combustion of chlorinated VOCs (CVOCs) will produce hydrogen chloride gas and as such, the oxidizer exhaust vapors will require further treatment by scrubbing with a caustic soda (i.e., sodium hydroxide [NaOH]) solution to neutralize the acid gas vapors, prior to discharge to atmosphere. The product of this neutralization is water with moderate levels of sodium chloride (salt).

As the site is heated, VOCs will be desorbed from the soil and volatilized along with the VOCs in DNAPL present in the subsurface. The VOC mixture will be extracted, along with steam and soil vapor (air), and delivered to the aboveground vapor treatment system. The lower boiling point VOCs will be extracted first, followed by the higher boiling compounds. However, under the ISTD process heat conducts radially out from the heater wells, such that a range of temperatures exist in the subsurface during the early stages of the heating process, and therefore, a range of VOC compounds will be volatized and extracted during the heat-up process.

The limit of VOC mass loading for a thermal oxidizer is the heat release resulting from combustion of those VOCs – an important consideration for a site such as SRSNE, with a substantial VOC mass to be extracted over a relatively short time. Therefore, it will also be important for the Vapor Treatment Needs and Options Evaluation to estimate the heating value for oxidation of the modeled composition. The heat released during combustion of the site VOCs is a critical design parameter for the selection and design of a thermal oxidizer system.

A number of different thermal oxidizer designs are available including once-through thermal oxidizers, catalytic oxidizers, regenerative thermal oxidizers, recuperative thermal oxidizers, etc. Given the high VOC mass loading expected at this site, on the order of 1MM to 2MM pounds of VOCs, and the relatively short duration of thermal treatment, expected to be on the order of 120-150 days, thermal oxidizer systems considered for this site must be capable of treating average VOC recovery rates estimated to be on the order of 300 to 600 pounds of VOCs per hour. Higher peak loads are expected.

Through review of new and existing analytical data and site DNAPL samples, a "representative average" or "typical" site-wide VOC mixture composition will be developed as part of the Vapor Treatment Needs and Options Evaluation. This model composition will also be used to develop a representative equation for the combustion that will occur in a thermal oxidizer.

Destruction of the hydrocarbon portion of the VOCs in the thermal oxidizer liberates the chlorine molecules from the CVOCs. Chlorine makes up an estimated 60% by mass of the Site COC mass. This leads to two important considerations. First, the liberated chlorine becomes hydrogen chloride gas which must be scrubbed and neutralized prior to release to atmosphere. Second, the liberated chlorine and hydrogen chloride gas can form extremely corrosive hydrochloric acid, thus materials of construction of the thermal oxidizer, wet scrubber and the interconnecting piping are important to the reliability of the system. The potential for corrosion and the selection of appropriate materials of construction will be addressed in the *System Design Evaluation Work Plan* (Attachment E to the RDWP).

Given the highly concentrated and variable nature of the Site COCs, it is anticipated thermal oxidation will be the most robust and capable primary vapor treatment technology for this Site. Thermal oxidation is presently the preferred vapor treatment approach for this Site. The Vapor Treatment Needs and Options Evaluation will proceed on this basis, examining mass loading capabilities of the various oxidizer designs, as well as the costs and benefits of various pre-treatment and parallel vapor treatment train scenarios to select the most flexible, roust and reliable configuration upon which the Preliminary Design will be based.

4.1.5 Combined Condensing and Carbon

This alternative simply consists of a combination of the condensing and vapor phase carbon treatment alternatives discussed earlier. In this combined approach, VOCs would be condensed through a cooling or compression and cooling. Vapor phase carbon, either sacrificial or on-site steam-regenerated, would then be used to treat the vapor effluent from the condensing system.

In this scenario, the majority of the VOCs would be condensed and recovered as NAPL, with residual VOCs collecting in the activated carbon beds. Waste streams requiring off-site disposal include recovered VOC NAPL and spent

carbon. Importantly, as discussed previously, there are a number of high-vapor pressure compounds, including cis-1,2-DCE, vinyl chloride and methylene chloride that are resistant to condensing and do not sorb well to activated carbon. Given the significant limitations of this alternative, this combination has been eliminated from further consideration.

4.1.6 Combined Condensing and Thermal Oxidation

In this option, condensing through cooling or compression and cooling is used as a pre-conditioning step prior to thermal oxidation. This alternative may warrant further consideration to improve both the robustness and reliability of a thermal oxidation system. A condensing system installed upstream of the thermal oxidizer(s) system can be used to manage peak VOC loading to maintain the vapor mass load within the thermodynamic limits of the thermal oxidizer, thereby eliminating the potential need to throttle back the in-situ heating process to stay below the operating limits of the thermal oxidizer. In this configuration, the condensing system will only be brought on-line, if needed, during peak VOC loading periods. Such operation would provide a margin of safety against exceeding the oxidizer capacity while minimizing the volume of condensed NAPL requiring off-site disposal and improving the robustness and reliability of the overall vapor treatment train.

The Vapor Treatment Needs and Options Evaluation will consider both the benefits and the capital and operating costs of such a combined system, as compared with extended heating or an additional oxidizer train in parallel. The benefits of such a combined system utilizing different vapor treatment technologies will enhance the operational flexibility to handle a potentially changing vapor composition over time. Further, a combined system may also improve robustness and reliability, in that if one system or component must be temporarily shut down for maintenance, the other system is available to continue treating the extracted vapors. This option will be retained for consideration in the Vapor Treatment Needs and Options Evaluation. The costs and benefits of the combined condensing/oxidizer system, including the estimated off-site NAPL disposal costs, will be compared against the cost of adding an additional oxidizer/scrubber system to manage peak loading.

5. Vapor Treatment Alternatives for Further Consideration

From the concept level evaluations conducted to date and summarized in the preceding sections of this Work Plan, thermal oxidation has emerged as the preferred vapor treatment alternative, either alone or in combination with other technologies that may include front-end condensing for resource recovery or peak load management, or vapor phase carbon for final effluent polishing.

The initial concept for treatment of the extracted VOC vapors from this site consists of two thermal oxidizer/scrubber treatment trains piped in parallel. During the initial and late stages of the heating process when extracted VOC mass load is lower, only one of the oxidizer/scrubber trains will operate, thus minimizing system operating costs. As VOC concentrations and mass loads increase, the second oxidizer/scrubber train will be brought on line to divide the VOC mass load between the two devices. This approach provides increased flexibility and reliability of the overall system. In this treatment process very little liquid VOC would be manifested off-site. Instead, the VOCs will be destroyed on site through combustion within the thermal oxidizers.

Oxidizer and scrubber designs, thermal treatment capacity, destruction and removal efficiency, materials of construction and energy utilization will be reviewed with manufacturers to determine an appropriate device(s) for the anticipated conditions as part of the Vapor Treatment Needs and Options Evaluation.

Initial consultations with several oxidizer vendors indicate that the anticipated peak mass load may require the use of substantially oversized oxidizers, with a significant amount of dilution air introduced. This could significantly increase both the capital and operating costs for the thermal oxidizer treatment trains. Therefore, the Vapor Treatment Needs and Options Evaluation will consider the alternative of including a condensing system upstream of the thermal oxidizer(s) that will operate only during peak VOC loading periods, to reduce the VOC mass entering the oxidizer(s).

The Vapor Treatment Needs and Options evaluation will examine these alternatives with special consideration given to the potential limitations identified in the preceding paragraphs. The following factors will be considered during the evaluation of these alternative(s):

- Proposed Process Flow Diagram
- Treatment Performance Capabilities
- COC-Specific Limitations
- Mass Loading Capacity (lb VOC/hr; Btu/hr)
- Capability to Handle Mass Load Fluctuations, Peak Loading
- Vendor Availability and Delivery Lead Time
- Permit Equivalency Compliance
- Vapor Emission Limits
- Required Destruction/Removal Efficiency (DRE)
- Anticipated Monitoring Requirements
- Cost Considerations
- Unit Capacity, Redundancy
- Fuel Consumption
- Materials of Construction
- Waste Streams
- Operating Modes

The outcome of the Vapor Treatment Needs and Options Evaluation will be the selection of the vapor treatment system that will carry forward into the Preliminary Design documents. it is important to establish the design approach for the vapor treatment system as early as possible to allow for critical component procurement planning, as some of the components may require custom designs and/or special materials of construction that could significantly impact the item's capital cost or extend standard vendor lead times.

Results of the Vapor Treatment Needs and Options Evaluation will be summarized in memo form and presented to the Agencies upon completion. The intent of presenting this information in advance of the Preliminary Design submittal is to inform the Agencies of the planned vapor treatment approach and to obtain some general feedback on the proposed design concept and Agency concerns, before the Preliminary Design package is submitted.