

**Environmental  
Resources  
Management**

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7 November 2002  
Reference: 143.65

Massachusetts Department of Environmental Protection  
Northeast Region  
205 Lowell Street  
Wilmington, MA 01887



Re: Response to Public Comments  
Release Abatement Measure Plan - Modification #1  
Former Raytheon Facility  
430 Boston Post Road  
Wayland, Massachusetts (the "Site")  
Permit No. 133939/RTN 3-13574

Dear Department Representative:

On behalf of Raytheon Company, Environmental Resources Management (ERM) has prepared this letter providing responses to comments prepared by CMG Environmental, Inc. (CMG), consultant to the Town of Wayland, and Mr. Stan Robinson regarding the Draft Release Abatement Measure Plan - Modification #1, dated 27 August 2002. CMG's comment letter, dated 8 October 2002, contains four comments concerning the proposed in situ chemical oxidation (ISCO) pilot study. Mr. Robinson's comment letter, dated 7 October 2002, contains three comments concerning the proposed ISCO pilot study and other Site-related issues. The format of this response letter is such that relevant portions of each comment are included in italics and responses are shown in plain text.

**CMG's Comments**

1) *On page 9, the RAM Plan Modification specifies that the two proposed additional monitoring wells will have ten-foot well screens. Since the expanded in-situ chemical oxidation (ISCO) pilot testing will focus on narrow vertical intervals, Wayland believes that five foot (or shorter) screened intervals would provide better pilot study results. Furthermore, we are concerned that the injected permanganate may leak from shallow injection into the deeper aquifer, or vice versa, via these monitoring wells. If you disagree, please explain why you prefer a ten-foot screened interval.*

The intent of the proposed monitoring wells is to monitor the effectiveness of the ISCO treatment across the entire vertical treatment interval (i.e., 13 to 30 feet below ground surface (BGS)). Based on volatile organic compound (VOC) data collected using the Waterloo Profiler at boring B-210, within the proposed pilot study area (Figure 4 in the Release Abatement Measure (RAM) Plan Modification), VOCs were detected in groundwater at depths ranging from 15 to 27 feet BGS. VOCs were not detected at the next vertical sample interval located at 35 feet BGS. In addition, VOCs have not historically been detected in well MW-43D, which is screened from 50 to 55 feet BGS. These data suggest that the maximum vertical extent of VOCs in this area appears to be between 27 and 35 feet BGS. Given that VOCs appear to be present throughout the silt unit, but not significantly below it, the pilot study was designed to ensure distribution of permanganate to a depth of 30 feet (i.e., just below the bottom of the silt layer) to react with any VOCs that may be diffusing out of the bottom of the silt layer. It is ERM's intent for permanganate to reach the lower "aquifer," as well as the upper "aquifer." Therefore, installation of the deep wells will not result in an adverse affect on the pilot study design.

To effectively monitor effects of the ISCO injection on groundwater quality, ERM has proposed to create three additional well couplets within the pilot study area by installing three wells to a depth of 30 feet BGS adjacent to three existing wells that are installed to 20 feet BGS. The existing wells have 10-foot long screens (i.e., 10 feet to 20 feet BGS), consistent with those proposed for the new wells (i.e., 20 to 30 feet BGS), which enables monitoring of the entire vertical treatment interval. One well couplet currently exists within the proposed treatment interval (i.e., MW-104 and MW-210) and both wells were constructed with 10-foot well screens. Alternatives to two 10-foot well screens at each location could potentially include four five-foot well screen or 10 two-foot well screens. However, given that permanganate will be injected under pressure as part of the pilot study, an increased numbers of boreholes would result in an increased likelihood of short-circuiting of permanganate to the ground surface via the borehole annulus. Therefore, it is our goal to minimize the potential for short-circuiting to the surface by minimizing the number of monitoring wells within the proposed treatment area.

The permanganate application is designed to occur over a series of fairly narrow vertical intervals under pressure to facilitate widespread lateral distribution of the oxidant. Following injection, the permanganate solution will sink through the underlying water column due to its higher

density, relative to water, resulting in better mixing of the oxidant with contaminated groundwater and soil. Therefore, though the injections will occur over fairly narrow vertical intervals, the oxidant should be distributed throughout the entire vertical treatment interval over time. Therefore, it is ERM's opinion that the installation of three new wells with 10-foot well screens will not affect any greater vertical transport of permanganate than that included in the pilot study design.

*2) Table 1 on page 9 indicates that you will analyze samples for chromium via EPA Method 200.7, given the rationale that ISCO could convert Cr<sup>3</sup> (trivalent) species to Cr<sup>6</sup> (hexavalent). Method 200.7 will provide results for total chromium, but you will also need to run samples via EPA Method 218.4 or 218.5 to obtain hexavalent chromium results, and then subtract any Cr<sup>6</sup> detection to obtain Cr<sup>3</sup> results.*

We appreciate your comment and have modified the RAM Plan Modification #1 (page 9) to indicate that we will analyze both total chromium by EPA Method 200.7 (i.e., by inductively coupled plasma/atomic emission spectroscopy (ICP/AES)) and hexavalent chromium by SM3500Cr-D/EPA 7196A (i.e., by colorimetric procedure). By using this approach, if chromium is detected, we will be able to speciate the valence state of the chromium. It is important to note that, though we considered the analytical methods recommended (i.e., EPA Methods 218.4 or 218.5), it is ERM's opinion that the combination of analytical methods selected (i.e., EPA Method 200.7 and SM3500Cr-D/EPA 7196A) will provide more accurate hexavalent chromium results. It is important to note that, though the hexavalent chromium analysis is a colorimetric procedure, ERM has proposed to analyze groundwater samples prior to permanganate injection and after consumption of residual permanganate to minimize the potential for interference from excess permanganate (i.e., purple water).

*3) The QA/QC description on page 10 does not indicate that Raytheon and ERM will submit sufficient samples for matrix spike duplicates (which is preferable to having the analytical laboratory select random samples out of their batch run for that day). Please include wording indicating you will direct the laboratory to take matrix spikes from site samples and provide sufficient filled sample containers to do so.*

We appreciate your comment and have modified the RAM Plan Modification #1 (page 10) to indicate that we will collect one sample per monitoring round for submission to the laboratory for analysis of Site-

specific matrix spike and matrix spike duplicates. ERM is in the process of modifying our sampling protocols for this and other sites to institute additional analytical quality assurance/quality control (QA/QC) procedure in accordance with the draft Massachusetts Contingency Plan (MCP) Analytical Data Enhancement Process.

*4)The RAM Plan Modification indicates that the [ISCO] reaction "does not generate any toxic by-products." Comments from persons attending the Public Involvement Plan (PIP) meeting on October 3, 2002 indicate a level of public concern regarding possible toxic by-products of the ISCO chemical reaction. The original RAM Plan (September 11, 2001) indicated that ISCO may also react with "natural organic carbons, such as humic and fulvic acids, and reduced minerals." However, neither the original RAM Plan nor the RAM Plan Modification list ISCO reaction products. Please provide chemical equations showing the actual reactants and products (including chemical intermediates, intential products, and likely by-products), based on available information.*

We appreciate your comment and have modified the RAM Plan Modification #1 (page 13) to include chemical formulas and an applicable reference indicating the end products of reactions between potassium permanganate and trichloroethene (TCE). The reaction included in the text indicates the following end products: manganese dioxide precipitate ( $\text{MnO}_2(\text{s})$ ), carbon dioxide ( $\text{CO}_2(\text{g})$ ), hydrogen ions ( $\text{H}^+$ ), chloride ions ( $\text{Cl}^-$ ) and potassium ions ( $\text{K}^+$ ). Similar reaction products are produced by reactions between permanganate and other chlorinated ethenes (e.g., 1,2-dichloroethene, perchloroethene, vinyl chloride). In some cases hydroxide ions ( $\text{OH}^-$ ) are formed rather than  $\text{H}^+$ . In the case of oxidation using sodium permanganate, sodium ions are produced. The  $\text{H}^+$  and  $\text{OH}^-$  ions affect the pH of groundwater (typically by less than one pH unit) and the remaining free ions ( $\text{K}^+$ ,  $\text{Na}^+$  and  $\text{Cl}^-$ ) typically form ionic salts. The following chemical formulas are provided for reactions between other chlorinated compounds and potassium permanganate:

Tetrachloroethene (PCE):  $4\text{KMnO}_4 + 3\text{C}_2\text{Cl}_4 + 4\text{H}_2\text{O} \rightarrow 6\text{CO}_2 + 4\text{MnO}_2 + 4\text{K}^+ + 12\text{Cl}^- + 8\text{H}^+$

Trichloroethene (TCE):  $2\text{KMnO}_4 + \text{C}_2\text{HCl}_3 \rightarrow 2\text{CO}_2 + 2\text{MnO}_2(\text{s}) + 2\text{K}^+ + \text{H}^+ + 3\text{Cl}^-$

1,2-Dichloroethene (DCE):  $8\text{KMnO}_4 + 3\text{C}_2\text{H}_2\text{Cl}_2 \rightarrow 6\text{CO}_2 + 8\text{MnO}_2 + 8\text{K}^+ + 6\text{Cl}^- + 8\text{OH}^- + 2\text{H}_2\text{O}$

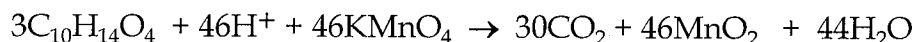
Vinyl chloride (VC):  $10\text{KMnO}_4 + 3\text{C}_2\text{H}_3\text{Cl} \rightarrow 6\text{CO}_2 + 10\text{MnO}_2 + 10\text{K}^+ + 3\text{Cl}^- + 7\text{OH}^- + \text{H}_2\text{O}$

Based on available information in the scientific literature, ISCO reactions have been shown to produce intermediates, which are short-lived due to the rapid reaction rates associated with permanganate oxidation (i.e., minutes to hours). Hydroxylation of olefins (e.g., TCE) has been known since 1895 and is accepted to occur as an initial reaction with the carbon-carbon double bond to form a cyclic hypomanganate ester (Siegrist et. al, 2001), which in turn is readily further oxidized or hydrolyzed by numerous reaction pathways. Carboxylic acid intermediates (formic, glyoxylic and glycolic acids) have also been detected during permanganate oxidation laboratory studies, but are rapidly oxidized to form the above-listed end products.

Oxidation does not oxidize all organic compounds – permanganate is ineffective on chlorinated ethanes, long chain hydrocarbons, fats, oils and greases. Permanganate is a comparatively weak oxidant, similar to hydrogen peroxide in strength. ERM has used alternative stronger oxidants (e.g., ozone, hydroxyl radical and persulfate); however, these are not required at the subject Site as the target compounds are readily oxidizable by permanganate alone.

Oxidation of naturally occurring organic compounds (NOM) have been studied for more than 40 years. "There is agreement that the major compounds produced by the oxidation of methylated and unmethylated humic and fulvic acids include aliphatic carboxylic, benzenecarboxylic acid and phenolic acids. In addition, smaller amounts of n-alkanes, substituted furans, and dialkyl phthalates are also generated (Siegrist et. al, 2001)." However, similar to the intermediates formed by oxidation of chlorinated compounds, intermediates of NOM oxidation are short-lived due to rapid reaction kinetics.

An example NOM oxidation reaction for humates is:



Oxidation may impact the natural oxidation-reduction (redox) conditions in the subsurface, imparting oxidizing conditions within the pilot area. ERM's experience is that these conditions attenuate, as the oxidant is consumed and aquifer conditions return to pre-treatment levels.

### **Mr. Robinson's Comments**

#### **1) SINGLE VERSUS MULTIPLE REPLACEMENT OF WETLANDS**

*All three Company scenarios assume excavation and single replacement (in the same location) of various wetland subparcels. However, where a Massachusetts builder proposes to disturb wetlands, double replacement is typically required. This means that the builder must convert non-wetland to wetland to the extent required to fulfill the replacement ratio. Builders have to do this even when disturbing an unpolluted wetland. I believe the reason for this requirement is that single-replacement wetlands provide "services" much less efficiently than established wetlands for a period of many years – exactly the same phenomenon Raytheon finds and relies on in its single-replacement-based net-benefit analysis.*

*Raytheon opportunistically proposes to leave uncleaned almost five acres of wetlands with excessive PCB levels, on the rationale that its single-replacement scheme has a negative net-benefit. Meanwhile, sufficient land are is available within the pertinent parcel to consider double-replacement and perhaps even triple- or quadruple-replacement. Adding multiples of wetland-replacement is a guaranteed path to not only positive net-environmental-benefit but also elimination of all excess PCB levels in soil. We need this. Raytheon should pursue this path.*

In response to this comment, ERM personnel visited the Town of Wayland Building Department to inquire as to their requirements for wetlands replication. The Town Building Department informed us that they had no policy regarding wetlands replication and that we should inquire with the Town Conservation Commission (ConCom). Upon doing so, the ConCom informed us that they had no written policy regarding wetlands replication and provided us with a copy of the Town of Wayland by-laws pertaining to Wetlands and Water Resources Protection (Chapter 194). Upon review of this document, ERM has not found any direct references to wetlands replication and anticipates that such issues would be addressed during the filing, review and public comment of the Notice of Intent (NOI) for wetland excavation.

#### **2) POURING OR FORCING PERMANGANATE INTO THE GROUND**

*Raytheon's enthusiasm for pouring or forcing permanganate into the ground (and ground water) instead of cleaning up the TCE its employees dumped there is certainly understandable. Apparently it would save a lot of money and work. The challenge we must pose to this is the same challenge we often fail to pose regarding any product or scheme: (a) prove its effectiveness, and (b) prove its safety.*

*If I understand correctly, test data indicates an effectiveness rate of approximately 84%; but we need an effectiveness rate of 99.97% to abate TCE from Raytheon's 17,000 ppb hot spot down to 5 ppb (the regulatory limit in drinking water). Accordingly, effectiveness remains unproven.*

*On the safety question, Raytheon proposes to convey permanganate in liquid form, employing approximately 40% concentration (if I understand correctly), and simply assumes negligible concentration post-reaction; but the 1999 Journal of Toxicology article, full text of which I forwarded separately, documents fatal poisoning from ingestion of a mere 0.01% concentration of potassium permanganate. Accordingly, safety remains unproven.*

Though permanganate is a relatively innovative approach to groundwater remediation, it is also a proven approach and accepted as a mainstream remedial approach by the Environmental Protection Agency (EPA). ERM personnel involved with this project have conducted a combined total of over 100 ISCO applications using various oxidants at sites throughout the United States. Raytheon has implemented ISCO pilot studies and/or full-scale remedial systems using permanganate at several sites within the United States.

A history of ISCO is presented in *Principles and Practices of In Situ Chemical Oxidation Using Permanganate* (Siegrist et al., 2001). In summary, chemical oxidation has been employed for decades in the wastewater treatment industry. More recently, in the mid- to late-1980s, chemical oxidation was implemented as an ex situ treatment technology for organic contaminants in groundwater that had been pumped from the subsurface. The literature indicates that in situ chemical oxidation (ISCO) to treat organic contaminants in groundwater began in the early 1990s. A brief review of readily available federal documents (EPA, 1998; ESTCP, 1999; GWRTAC, 1999) and conference proceedings (The Second and Third International Conferences on Remediation of Chlorinated and Recalcitrant Compounds, 2000 and 2002, respectively). indicates widespread application of ISCO to treat TCE in groundwater in the United States.

Based on laboratory data presented in Siegrist et al. (2001) and laboratory results from ERM's treatability laboratory, it is possible to destroy greater than 99% of TCE in groundwater. However, at this time, Raytheon is not proposing remedial activities for the northern Site area in which 17,000 micrograms per liter (ug/L) of TCE was detected. As part of the ongoing

Site assessment process, ERM will further characterize this portion of the Site and evaluate a variety of potential remedial technologies, including ISCO. One of the key evaluation criteria will be the ability of the selected technology to reduce the highest detected TCE levels to concentrations at or below applicable GW-1 cleanup standards (i.e., drinking water standards).

Thank you for submitting the journal article (i.e., October 1999 Journal of Toxicology: Clinical Toxicology paper, entitled "Fatal potassium permanganate intoxication of an infant") pertaining to potential health and safety issues associated with permanganate.

It is the goal of the pilot study to apply permanganate at the Site in a manner that is consistent with industry standard health and safety practices resulting in no adverse impact to human health. Appropriate health and safety protocol will be followed throughout the pilot program. Though ERM intends to apply a 15% sodium permanganate solution, this concentration will become significantly diluted once it mixes with groundwater in the subsurface, resulting in an initial in situ concentration of less than 1%. Given the propensity for permanganate to react with both organic contaminants as well as naturally occurring organic matter, the relatively slow groundwater flow gradients at the Site (0.06 feet per day, Phase II report, dated 28 November 2001), and the absence of nearby drinking water supply wells, ERM believes that the permanganate applied as part of the pilot study will be consumed prior to migrating to a location where it could be extracted from the subsurface and ingested.

3) *REGULATORY LIMITS VERSUS BACKGROUND AS THE TREATMENT TARGET* A modest proposal: To minimize harm to public health, I would propose that PCBs, TCE, and all other known pollutants be targeted for abatement to bona fide background levels...

Raytheon will comply with applicable state and federal regulations to define appropriate cleanup goals for the Site. Where applicable and appropriate, Raytheon will consider abatement to background levels. However, in certain portions of the Site, this may not be technically feasible.



### *References*

Field Applications of In Situ Remediation Technologies: Chemical Oxidation, September 1998, United States Environmental Protection Agency, EPA 542-R-98-008, 31 pp.

Siegrist, R.L., M.A. Urynowicz, O.R. West, M.L. Crimi and K.S. Lowe, 2001, Principles and Practices of In Situ Chemical Oxidation Using Permanganate, Battelle Press, Columbus, OH, 348 pp.

Technology Status Review In Situ Oxidation, November 1999, Environmental Security Technology Certification Program (ESTCP), 42 pp.

The Second International Conference on Remediation of Chlorinated and Recalcitrant Compounds, 2000, Monterey, CA.

The Third International Conference on Remediation of Chlorinated and Recalcitrant Compounds, 2002, Monterey, CA.

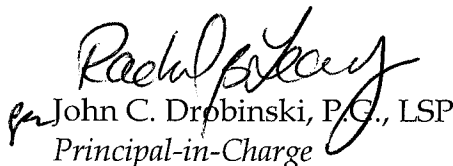
Yin, Y and H.E. Allen, July 1999, In Situ Chemical Treatment, Ground-Water Remediation Technologies Analysis Center (GWRTAC), Pittsburgh, PA, 74 pp.

If you have any questions or comments please contact Mr. Ron Slager of Raytheon at (508) 490-1707.

Sincerely,



R. Joseph Fiacco, Jr., P.G.  
Project Manager



John C. Drobinski, P.G., LSP  
Principal-in-Charge

rjf

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Public Repository (Primary Location), Former Raytheon Facility,  
Wayland Public Library, Louise Brown, 5 Concord Road,  
Wayland, MA 01778

Public Repository (Secondary Location), Former Raytheon Facility,  
Wayland Town Hall, 41 Cochituate Road, Wayland, MA 01778