STEVENS
Institute of Technology

Stevens Institute of Technology
Castle Point on Hudson
Hoboken, NJ 07030
201.216.5340
Fax: 201.216.5352

Office of the Vice President
Facilities, Support Services
and Construction Management Program

Mr. John Meditz, Chairman
Weehawken Planning Board
Weehawken Township Planning Office
2 50th Street
Weehawken, NJ 07086

March 08, 2007

Re: Athletic Facility Construction

Dear Mr. Meditz:

Enclosed is the report of findings in connection with the construction of the Athletic Facility located on the Hudson River as requested by Mayor Turner. If you should have any questions on this topic you may call me at 201-216-5340 at any time.

Very truly yours,

Henry P. Dobbelaar, Jr., P.E.
Vice President Facilities/ Support Services

Center for Environmental Systems
Stevens Institute of Technology
Castle Point on Hudson
Hoboken, NJ 07030
Tel: 201.216.5326
Fax: 201.216.8303
http://www.ces.stevens-tech.edu

3. Groundwater Remedial Investigation Report for Port Imperial South at Weehawken
   Port Imperial South at Weehawken
   Weehawken Township
   Hudson County, New Jersey
   NJDEP case No. 97-08-15-0025-05
   Prepared by: EcolSciences, Inc (October 2004)
4. Geotechnical Report
   Weehawken Apartments
   Weehawken, New Jersey
   Prepared by: McLaren Engineering Group.

2.2. Cr and Cr(VI) concentrations:

The site encompassed areas with elevated levels of Cr(VI) and Cr concentration. These areas were encountered in Lots A, B, and D. The Cr(VI) and Cr concentrations in lot A ranged from Non Detect (ND) to 3500 mg/Kg and 7.9 to 11800 mg/Kg, respectively whereas these concentrations in lot B ranged from ND to 4030 mg/Kg and ND to 5910 mg/Kg for Cr(VI) and Cr, respectively. Finally, the measured Cr(VI) concentration ranged from ND to 9580 mg/Kg in lot D. None of the measured Cr concentration exceeded the soil cleanup criteria for NJDEP Residential Direct Contact Soil Cleanup Criteria (RDCSCC) level at 120,000 mg/Kg. Conversely, the measured Cr(VI) concentrations exceeded the RDCSCC level of 240 mg/Kg at many locations.

2.3. Soil pH values:

A survey of the pH values indicted neutral to moderately alkaline conditions with measured pH values hovering around 8.

2.4. Groundwater Investigation:

The groundwater investigation indicated that the lands encompassed within the Port Imperial south project site generally drain in an easterly direction toward the Hudson River and wells close to the river exhibited tidal influences. However, none of the monitoring wells Cr(VI) concentration exceeded the NJ Class IIA Ground Water Quality Criteria (GWQC) level at 100 PPB.

Center for Environmental Systems
Stevens Institute of Technology
Castle Point on Hudson
Hoboken, NJ 07030
Tel: 201.216.5326
Fax: 201.216.8303
http://www.ces.stevens-tech.edu

1. Introduction

In January 2006, the Center for Environmental Systems (CES) at Stevens Institute of Technology was invited to evaluate a remediation plan for Cr(VI) contaminated areas at Weehawken Waterfront park site. The waterfront Park is presently undergoing an approved environmental remediation program that is being monitored by NJDEP. Experts from CES reviewed the Cr(VI) remediation plan and conducted additional targeted testing to better understand the properties of the existing soil, specifically its mineralogical characterization with regards to Chromite Ore Processing Residue (COPR). Therefore, the evaluation process comprised of reviewing a list of reports provided by the Weehawken Township, and performing additional experimental work that was deemed necessary to complement the existing experimental data.

2. Remedial plan review

2.1. List of reviewed reports

The Weehawken Township provided CES personnel with four reports that contain pertinent information on the physical and goechemical characteristics of the site and the chromate remediation plans. The following is a list of the documents that were provided to CES:

1. Final Remedial Investigation Report
   Port Imperial South at Weehawken
   Weehawken Township
   Hudson County, New Jersey
   MOA case #97-8-15-0025-8
   Volumes I-III
   Prepared by: EcolSciences, Inc (October 2000)
   (Partial Report – Cr(VI) related material)

2. Remedial Action Work Plan
   Port Imperial South at Weehawken
   Weehawken Township
   Hudson County, New Jersey
   MOA Case #97-8-15-0025-8
   Prepared by: EcolSciences, Inc (October 2001)
   (Partial Report – Cr(VI) related material)

Center for Environmental Systems
Stevens Institute of Technology
Castle Point on Hudson
Hoboken, NJ 07030
Tel: 201.216.5326
Fax: 201.216.8303
http://www.ces.stevens-tech.edu

2.5. Cr(VI) Remedial Action Work Plan:

The remedial plan for the Cr(VI) contaminated areas calls for the installation of either a standard soil cap, an impermeable "chromium cap", or an impervious surface that are elements of the site development. The NJDEP is in agreement that sites with Cr(VI) concentration greater than 100 mg/Kg require a chromium cap whereas sites with Cr(VI) concentration less than 100 mg/Kg are to be covered with standard soil caps or by site improvements. According to the remedial plan, areas with Cr(VI) in excess of 100 mg/Kg will be capped with an impermeable high density polyethylene (HDPE) liner, which in turn will be covered with a soil cap or site improvements. The HDPE liner is 40-mil in thickness, consistent with the existing NJDEP-approved hexavalent chromium liner already in place on the southern-most portion of the park. This liner will completely cover the chromate waste materials within the Weehawken Waterfront Park.

3. Experimental work

3.1. Weehawken soil samples

The mineralogical characterization is of utmost important to ascertain whether the site contains any COPR material. Consequently, CES requested the random collection of soil samples from areas with elevated Cr(VI) concentration. On March 20, 2006, the CES staff extracted three random samples (S1, S2, and S3) from an excavation area in Lot A. These samples were characterized for pH, Cr(VI) and mineralogy.

3.2. Experimental methodology

3.2.1. Physicochemical analyses

The pH and water content were measured according to ASTM methods D 4980-89 and D 2216-98 [1], respectively. Total Cr(VI) was measured by the U.S. EPA methods 3060A [2] and 7196A [3]. All sample analyses were conducted with duplicates and averaged values were reported.

3.2.2. X-ray Powder Diffraction (XRPD) analyses

The mineralogical characterization was performed using XRPD analyses. Prior to XRPD analyses, all samples were air dried for 24 hours and then pulverized to pass through a US standard #400 sieve (38 μm). The resulting powder was mixed with 20% w/w internal standard (α-corundum, Al_2O_3) (Sawyer, Lot. No. C04-AO-41) in order to quantify amorphous content. Step-scanned X-ray diffraction patterns were collected by

Center for Environmental Systems
Stevens Institute of Technology
Castle Point on Hudson
Hoboken, NJ 07030
Tel: 201.216.5326
Fax: 201.216.8303
http://www.ces.stevens-tech.edu

the Rigaku DXR-3000 computer-automated diffractometer. XRPD analyses were performed at 40 kV and 40 mA using a diffracted beam graphite-monochromator with Cu radiation. The XRPD patterns were collected in the 2θ range of 5° to 65° with a step size of 0.02° and a count time of 3 seconds per step. The XRPD patterns were analyzed using Jade software version 7.1 [4] with the PDF-2 reference database from the International Center for Diffraction Data database [5] and the Inorganic Crystal Structure Database, release 2005 [6].

4. Results and discussion

4.1. Remedial plan overview

The NJDEP approved Cr(VI) remedial plan will prevent the exposure of the general public to Cr(VI). However, if the chromium cap were to be compromised, then Cr(VI) may be brought to the surface. A proper maintenance plan will detect, alleviate and prevent any compromises.

4.2. Physicochemical analyses

The pH, water content and Cr(VI) concentrations of each sample are presented in Table 1. The data for Cr(VI) concentrations indicate that this location is a Cr(VI) hot spot. The sample pHs were lower than those of COPR and below the stability region pH of swell causing minerals that induce heave behavior in COPR. Moreover, a review of the pH values (provided by EcolSciences) throughout the site indicated similar values to the ones measured at Lot A.

Table 1. Physicochemical Properties of Weehawken Samples

Samples	Water content (%)	pH	Cr(VI), mg/Kg
S-1	11.7	7.92	2872
S-2	3.62	8.18	1603
S-3	5.31	7.98	2634

4.3 X-ray Powder Diffraction (XRPD) analyses

Some chromium deposition sites experienced excessive swell and heave which compromised overlaying structures and embedded infrastructures. The cause of heave was traced back to the nature of the chromium waste which comprised of metastable mineral phases. These wastes were identified as COPR with mineral phases such as brownmillerite, katoite, periclase, brucite, calcite, portlandite, calcium aluminum chromates, ettringite, and hydrotalcites. Therefore, it is important to ascertain whether

Center for Environmental Systems
Stevens Institute of Technology
Castle Point on Hudson
Hoboken, NJ 07030
Tel: 201.216.5326
Fax: 201.216.8303
http://www.ces.stevens-tech.edu

the chromium contamination at the Weehawken Waterfront park site is due to the presence of COPR.

Quantitative XRPD results and XRPD patterns are presented in Table 2 and Figure 1, respectively. The mineralogical characterization of the Weehawken samples showed that the soil is comprised mostly of silicate phases, which are not similar to the mineralogy of COPR materials. The heaving phenomena at COPR deposition sites are mainly caused by the hydration of major COPR minerals. Additionally, ettringite is one of the major phases which lead to swell in COPR materials [8]. None of these major COPR phases were identified based on XRPD analyses.

Overall, the Weehawken samples can be considered as sandy soils due to their high quartz content. At this site only soil minerals such as quartz, dickite, muscovite and albite were identified. It can be concluded that the mineralogy obtained in these samples was not similar to the COPR mineralogy; therefore, no heave is expected to develop that would compromise the integrity of the installed Cr(VI) liner.

Table 2. Quantitative XRPD Results for Weehawken Samples[a]

compound	chemical formular	PDF[b]	S-1	S-2	S-3
dickite	$Al_2Si_2O_5(OH)_4(HCONH_2)$	01-074-1758	5.1	1.5	0.8
muscovite	$(K,Na)(Al,Mg,Fe)_2(Si_{3.1}Al_{0.9})O_{10}(OH)_2$	07-0042	17.2	9.1	6.1
clinochlore	$(Mg,Fe)_6(Si,Al)_4O_{10}(OH)_8$	29-0701		3.3	3.9
albite	$NaAlSi_3O_8$	09-0466	18.8	24.0	14.4
calcite	$CaCO_3$	47-1743	3.6	1.5	1.9
quartz	SiO_2	46-1045	31.3	34.5	48.9
microcline	$KAlSi_3O_8$	19-0932		15.0	16.4
pargasite	$(Na,K)Ca_2(Mg, Fe)_4Al(Si_6Al_2)O_{23}$	47-1799		6.3	
maghemite	Fe_2O_3	39-1346	17.6	3.6	
nordstrandite	$Al(OH)_3$		2.7		
amorphous			3.6	1.2	7.6

[a]All results in % w/w dry solid. [b]Powder diffraction file.

Center for Environmental Systems
Stevens Institute of Technology
Castle Point on Hudson
Hoboken, NJ 07030
Tel: 201.216.5326
Fax: 201.216.8303
http://www.ces.stevens-tech.edu

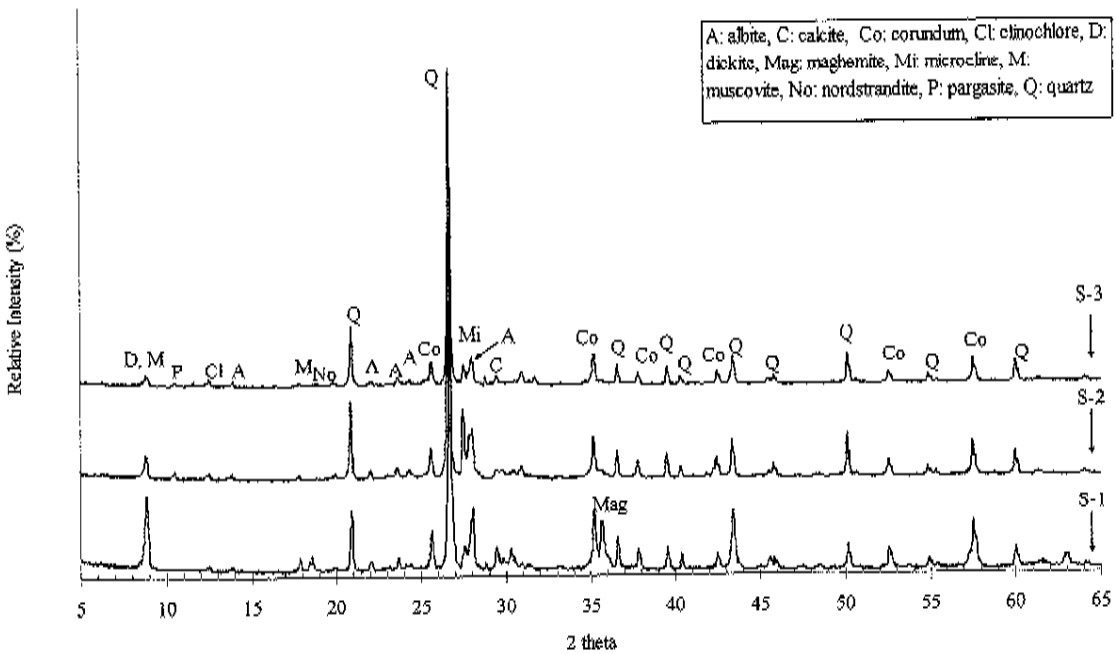

Figure 1. XRPD patterns of Weehawken Samples

5. Conclusion

The evaluation of the chromium and Cr(VI) concentrations within the Weehawken Waterfront park site indicated that Cr concentrations did not exceed the RDCSCC level whereas Cr((VI) concentrations exceeded that level at many locations. The mineralogical characterization indicated that the site mineralogy is not similar to COPR mineralogy. Furthermore, the measured pH values at the site, of around 8, are not similar to COPR pH. Public exposure to elevated Cr(VI) concentrations is controlled by a NJDEP approved Cr(VI) remediation plan that has been implemented at the site. The Cr(VI) remedial plan includes a standard cap for areas with Cr(VI) concentrations below 100 mg/Kg (18 inches of clean soil or impermeable surfaces such as buildings or roads) and a chromium cap where Cr(VI) concentrations exceed 100 mg/Kg. Therefore, the NJDEP approved Cr(VI) remedial plan prevents Cr(VI) exposure of the general public using the site facilities.

Center for Environmental Systems

Stevens Institute of Technology
Castle Point on Hudson
Hoboken, NJ 07030
Tel: 201.216.5326
Fax: 201.216.8303
http://www.ces.stevens-tech.edu

References

[1] American Society for Testing and Materials, Annual book of ASTM Standards, Soil and Rock, 2000, Vol. 4.08.
[2] U.S. Environmental Protection Agency, Alkaline Digestion for Hexavalent Chromium, Method 3060A, Washington D.C. 1996.
[3] U.S. Environmental Protection Agency. Chromium, Hexavalent (colorimetric), Method 7196A, Washington D.C. 1992.
[4] Material's Data Inc, Jade, Version 7.1, 2005, California, U.S.A.
[5] International Centre for Diffraction Data, Powder Diffraction File PDF-2 Database Release; ICDD: Newtown Square, PA, 2002.
[6] Inorganic Crystal Structure Database. Fachinformationszentrum Karlsruhe, Germany, 2005.
[7] Dermatas D., Chrysochoou M., Moon D.H., Grubb, D.G., Wazne M., Christodoulatos C., Ettringite-induced heave in chromite ore processing residue (COPR) upon ferrous sulfate treatment, Environmental Science and Technology, in press.
[8] Moon D.H., Dermatas D., Chrysochoou M., Shen G. An investigation of the heaving mechanism related to chromite ore processing residue, Journal of ASTM International, 2006; 3 (6).

Christos Christodoulatos

Mahmoud Wazne