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Evaluation of long-term Performance of Stabilized Sediment for Beneficial Use

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16. Abstract

Over the past twenty years, the state of New Jersey has accepted over 30 million cubic yards of material that have many practical uses. This study was conducted to develop a methodology based on existing studies, reviewing records, and visiting field sites. A total of 6 sites in NJ where stabilized dredged materials (SDM) had been used to augment and/or replace borrowed materials – "beneficial-use applications" were identified for inclusion in this study. Each site had different types of soil, waste, pollution (organic and inorganic), and employed different binder and remediation systems.

The data revealed no evidence of chemical releases at any of the sites, probably because these sites were capped or filled with SDM. In addition, the geotechnical requirements of the material were generally met. The only exception took place at the National Lead site, most likely due to the initial mixing during stabilization.

Based on the six sites that were studied, we conclude that SDM does not break down or fail to maintain its design function. Further investigation of this material should include laboratory studies that use an accelerated testing regime to determine what conditions could result in material failure.

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1 INTRODUCTION

Dredging is the removal of sediments and debris from the bottom of rivers, harbors, and other water bodies for navigational or environmental reasons (EPA and USACE 2007, Welch, Mogren et al. 2016). In urban waterways, much of this material contains a wide range of contaminants, from heavy metals to oil and pesticides. The presence of environmental contaminants can make disposal of dredged material difficult due to environmental regulations that can limit the options for disposal locations. Typically, the cheapest and easiest method for disposal of dredged material is open ocean disposal. However, the ability to do this has been curtailed due to increasingly stringent environmental regulations.

In the NYNJ Harbor, ocean dumping was done since the mid 1800's at specific locations in the NY Bight. Later, the Office of Supervisor of New York Harbor was established by an act of Congress in 1888 to address the increasing need for disposal of the assorted waste materials from the harbor. The Harbor Supervisor, acting through the Office of the Chief of Engineers (of the U.S. Army Corps of Engineers), was responsible for the designation of specific disposal sites and for ensuring that ocean disposal would not be detrimental to navigation or pollute adjacent beaches. (ASCE, 2019 website). From 1914 until 1977, when the U.S. Environmental Protection Agency (EPA) designated an interim ocean dredged material disposal site, the general area reserved specifically for a "mud dumping ground" more than 200 million cubic yards (MCY) of dredged material were deposited there. In 1984, EPA officially designated the interim site as a dredged material ocean disposal site, referring to it as the "Mud Dump Site". From 1976 to 1997, when more reliable disposal volume records were kept, approximately 115 MCY of dredged sediment were disposed within the boundaries of the Mud Dump.

In September 1997, the EPA de-designated and terminated the use of the Mud Dump and simultaneously re-designated the site and surrounding areas that had been historically used for dredged material disposal as the Historic Area Remediation Site (HARS) (40 CFR Sections 228.15(d)(6); see 62 Fed. Reg. 46142 (29 August 1997); 62 Fed. Reg. 26267 (13 May 1997)). Currently, the only material that is "suitable" for placement at the HARS site is clean material that is used to cap the existing material that has been historically placed. As a result, any material that is deemed "unsuitable" for placement at the HARS must be disposed of in some alternative manner. As a result, the Port of NY/NJ and the surrounding region was forced to pursue a policy of environmentally sound beneficial use of dredged material (Barbour, Gerritsen et al. 1999, Douglas, Maher et al. 2005, Makusa 2015).

In 1996, a Dredge Material Management Plan for Port of NY and NJ was completed. The plan specified particular dredge material disposal alternatives to address the decreasing options for dredge material placement. The recommended activities included: developing an upland beneficial use program, evaluating decontamination methods, developing confined disposal facilities, investigating alternative techniques, developing a regional dredged material management plan, increasing the role of the Harbor Estuary Program in assessing and managing polluted sediments, and project dredging (USACE, 1996). Several techniques for treatment and disposal of "unsuitable" sediments have been investigated including: natural recovery, bioremediation, landfill, in-situ capping, use as fill material and as a raw material for building products such as bricks, blocks, tiles, and top soils (McDonough, Boehm et al. 1999, USACE 2004).

These regulations resulted in one strategy that is commonly used in New Jersey, stabilization and beneficial use of the stabilized dredged material (SDM) as a capping or filling material for landfills, industrial sites, and abandoned mines. It has also been used as road base and the construction of road embankments. Sediment solidification/stabilization (S/S) is a technique to treat contaminated sediments, sludges or other wastes through the addition of cement, fly ash, lime and/or chemicals to create soil aggregates. S/S is one of the most common in situ technologies used at Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites for source control and was the second most commonly used in situ source treatment control in fiscal years 2005-2008. Since the 1950's, Portland cement (PC) has been the primary binding agent used in sediment stabilization and solidification (S/S) projects (Hills, Gunning et al. 2015). It has been applied to a wide range of wastes and is generally chosen for its ability to chemically bind and fix free liquids or hazardous contaminants, decrease permeability, and encapsulate waste particles (Wilk 2004).

Several experiments have been conducted over the past 20 years to investigate the effectiveness of PC as well as other pozzolanic materials and alkaline additives in enhancing the strength of soft marine sediments and stabilizing associated contaminants. Successful treatment by S/S relies on a combination of reduced leachability (chemical stabilization) and lowered permeability (solidification), which combine to minimize the release of contaminants from the treated SDM matrix. These properties can make the SDM suitable for use in engineering applications. The use of known contaminated sediment, though stabilized, requires the evaluation of potential environmental. The potential mobility of toxic, hazardous, or harmful substances through the stabilized sediment must be well understood prior to its use in engineering applications (Hakstege 2007). Successful stabilization-solidification of the dredged sediments and the performance of the SDM is related directly to methods and materials of stabilization. Therefore, it is important to understand the mechanical properties (e.g. Strength and compressibility) and durability of the SDM (Makusa 2015).

Over the past twenty years over 30,000,000 yd^3 of dredged material has been stabilized and beneficially reused at several sites throughout NJ and the surrounding region. These sites include parking lots, truck depots, golf courses, etc. Each of these uses has performance requirements that must be met for placement of the material. However, the long term performance of the stabilized material is not well documented due to a limited record of projects, and the fact that when SDM is used for construction, at the completion of that construction, the site is occupied and unless there is a catastrophic failure, there is limited interest, on the site owner's part, to investigate their site. A literature review was conducted to identify SDM placement sites in the U.S. and throughout the world where long term monitoring of material integrity was measured. Subsequent to the literature review, a strategy to assess long term integrity of SDM placement sites was developed and applied at placement site throughout NJ. This evaluation was completed primarily through exhaustive records searched at the NJDEP and NJDOT, and site visits.

1.1 BENEFICIAL USE PROJECTS

Beneficial Use of dredge sediment is an ever expanding field. The constant need for dredging coupled with the inherent difficulties associate with placing impacted urban sediments has led to the creation of an entire industry revolving around the Stabilization and placement of SDM. One of the highest concentrations of beneficial use projects is in the NYNJ Harbor region. A partial list of these project is presented in Table 1 (Maher et al. 2013). However, this list was current as of 2013, since then many of these sites have received addition volumes of sediment and were closed and subsequently redeveloped or slated for redevelopment, as commercial, residential, and public open spaces.

Table 1 Beneficial Use Sites NJ Region

Project	Municipality	Volume Placed at of 2012 (cubic yards)	Status
1E Landfill	Bergen County NJ	1,000,000	Closed
Bark Camp Mine	Center County, PA	400,000	Closed
Bellmawr Landfill	Bellmawr, NJ	335,500	Closed
DuPont Graselli	Linden, NJ	548,277	Closed
Elizabeth Seaport Park	Elizabeth, NJ	380,000	Closed
Encap Golf	Bergen County, NJ	1,200,000	Closed/Shut Down
FDP Enterprises	Secaucus, NJ	420,000	Closed
Fresh Kills Landfill	Staten Island, NY	800,000	Closed
Global Landfill	Jersey City, NJ	148,055	Closed
Henry Harris Landfill	Mullica Hill, NJ	40,000	Closed
Hercules	Burlington Twp., NJ	250,000	Closed
Keegan Landfill	Hudson County, NJ	190,000	Closed
Koppers Coke	Kearny, NJ	1,071,000	Open
Lincoln Park Landfill	Jersey City, NJ	795,556	Closed
Linden Landfill	Linden, NJ	500,000	Closed
NJ Turnpike Site	Jersey City, NJ	60,000	Closed
NL Industries	Sayreville, NJ	388,289	Closed
OENJ Bayonne	Bayonne, NJ	2,000,000	Closed
OENJ Elizabeth	Elizabeth, NJ	800,000	Closed
Overpeck Landfill	Bergen County, NJ	290,000	Closed

Penn and Fountain Landfill	Brooklyn, NY	209,000	Closed
Port Liberty	Jersey City, NJ	200,000	Closed
Port Reading Business Park	Woodbridge, NJ	131,000	Closed
Prologis Teterboro	Teterboro, NJ	276,565	Open

Although the largest Beneficial Use market has been the NYNJ Harbor, it has also been employed at other locales throughout the US and globally. One of West Coast biggest reuse projects is a joint project between the Port of Oakland and the USACE. About 4.5 million cubic yards of SDM was placed in an upland disposal facility in order to deepen the Port of Oakland to 42 feet. On the footprint of the Galbraith golf course, a large confined disposal facility was created. The golf course was shut down and slurried dredging material was transported from the port to the site over a three-year period (USEPA 1998). The Moss Landing Harbor in California was a small beneficial use project. Due to elevated pesticide levels and a deficient, non - suitable upland site for disposal, the Moss Landing Harbor District (MLHD) was unable to dredge its commercial and recreational harbor. The MLHD used cement additives, a waste product from a refractory plant to provide the material for construction of a road, parking lot, and the development of a new recreational use facility. To date, around 110,000 cubic yards of the site have been used in a similar manner (HLA, 1999). In Squalicum Harbor, WA 40,000 cubic yards of impacted material was beneficially used as landfill cover at a nearby facility once it was deemed unacceptable for open water placement.

Globally, beneficial use of impacted sediments is a practice that is gaining momentum, especially in the areas of port expansion and land reclamation. One example is the current expansion of the Port of Gothenburg, Sweden. The expansion will utilize approximately 1,000,000 cubic meters of sediment that is contaminated with TriButyl Tin to expand their port operations.

1.2 PERFORMANCE AND LONG-TERM DURABILITY OF SOLIDIFICATION / STABILIZATION (S/S)

Sediment Solidification/Stabilization (S/S) technique has been used to treat sediments for many years now. There are a lot of concerns that have been raised in recent years regarding the performance of this technique and its long term durability (Conner, 1990; Borns, 1997; Glasser, 1997; Loxham et al., 1997).

The main concerns can be attributed to

(i) Uncertainties in test methods.
(ii) Observed deficiencies in the process application.
(iii) Observed lack of chemical binding in crushed samples of treated waste, suggesting that contaminants could leach out under certain conditions.
(iv) Uncertainties of performance arising from anticipated behavioral degradation of the material over time.

Degradation ranges between two extremes: complete release of the contaminant in a relatively short period of time, and a gradual release over a long period of time. Degradation of S/S material with complete release of the contaminant in a relatively short time period is unacceptable though unlikely. On the other hand, a gradual release of some contaminants over a long period of time is more likely to occur.

A comprehensive sediment treatment method can be provided by the solidification/stabilization (S/S) technique. The S/S technique helps by improving strength, decreasing compressibility and reducing mobility of the contaminant. These properties make the stabilized dredged material (SDM) have numerous engineering applications. Acceptance of new materials technology require vast research in its short and long term performance. These uncertainties can be quantified by obtaining real-time long-term data. However, despite the widespread use of S/S techniques, there is little evidence of long-term validation and still no direct evidence of time-related material performance in the field (Kirk, 1996). Validation of the long-term effectiveness of contaminated ground and waste treatment methodology is essential for its success and assessment of its sustainability.

The performance of solidification/stabilization (S/S) treated materials should take into account the behavior of the material both immediately after implementation, as well as the long-term aspect of material durability and site monitoring/maintenance. The primary purpose of S/S technique is to decrease the flux of contaminant that leaches from the contaminant source to the acceptable standard set forth in the site-specific remediation goal. Several studies and predictive models suggest that a properly designed S/S remedy which accounts for the contaminant properties and the disposal/management scenario conditions can be expected to last for decades or even centuries. Because contaminants remain in place, a gradual release of the contaminants over a long period of time would constitute a failure in the technology. This could be the result of inadequate site or contaminant characterization, poor design, or poor implementation of the S/S remedy (Passify 2010, Solidification/Stabilization 2011).
There is a need for observing and understanding the behavior of S/S materials over time in order to assess and understand its durability and long-term performance. Several studies have been conducted to observe the behavior of S/S materials (typically soils, not sediment) over long periods of time. These studies cover the treatment of contaminated soil and waste. The following case studies are based on S/S treated material and tests administered one year after treatment.

Case 1: In Douglassville, USA, a polluted site was treated ex-situ using a mobile field blending unit (de Percin and Sawyer, 1991). The site was polluted with different concentration levels of lead, oil and grease, and low levels of volatile and semi-volatile organics at different locations. Six locations were selected for treatment. The soil was excavated, screened and treated from the designated locations by combining with Portland cement and a proprietary additive (Chloranan). The additive has been added to neutralize the effect of organics on cement hydration. The blended mixtures were placed in molds for curing for 48-96 hours, prior to being de-molded, and placed into the excavation holes which had been modified by adding a liner and some clean soil. After 28 days, 9 months and 18 months, core samples were taken from the blocks and analyzed for properties such as bulk density, moisture content, UCS, freeze-thaw, wet-dry durability, permeability and TCLP leachate. Microstructural testing was also carried out using SEM, optical microscopy and XRD. The investigation concluded that (i) the test blocks had little to no deterioration observed, (ii) while the heavy metals remained immobilized, the organic concentrations reduced over time, and (iii) the healing process continued after 18 months.

Case 2: In Los Angeles, USA, another laboratory experiment was conducted to examine the behavior of two arsenic salts treated with different binders over time (Akhter et al., 1997). The waste was treated with multiple binders including Portland cement (PC), gypsum-free PC, fly ash (FA), silica fumes, sodium silicate, bentonite, organoclay, white cement, PC with air entraining agent and high alumina refractory cements (Lumnite and Refcon). The wastes were $NaAsO_2$ and $Na_2HAsO_4 .7H_2O$. Before testing at 28 days, 1 year and 3 years after mixing, the treated samples were placed in vials, sealed and kept at room temperature. The analysis included TCLP leachability, magic angle spinning nuclear magnetic resonance spectroscopy (MAS-NMR), XRD and derivative thermogravimetry (DTG). The key finding of this research was that PC-FA mixtures showed substantial respeciation during long healing periods and that the changes in the matrix were correlated with increased leachability. It was crucial to undertake long-term studies in order to understand the behavior of matrices likely to undergo respeciation and the resulting changes in leachability over long periods of healing.

Case 3: An Electric Power Research Institute (EPRI) - funded project carried out 10 years after the implementation of S/S at a former MGP site contained geotechnical, chemical, leaching, and solid-phase geochemical analysis of samples taken from the site. Contaminant transport modeling was used to predict the leaching potential at the site using the sampling data. The material, after treatment, was found to meet the performance standards as intended. Moreover, concentrations of pollutant at the POC monitoring were predicted for at least 10,000 years, to ensure that it continued to meet the performance criteria (EPRI 2003).

Case 4: In another study, a research consortium led by the Greenwich University, New Hampshire University, and INERTEC, carried out a research project called Performance Assessment of Solidified/Stabilized Waste-forms (PASSiFy). The PASSiFy Project's purpose was to evaluate the time-dependent performance of the S/S technique in 10 sites where S/S was implemented, between 1989 and 2006. Contaminant classes in these sites included heavy metals, PCBs, hydrocarbons of petroleum, PAHs, acid wastes, tar, dioxins, and constituents of creosote and coal. Geotechnical, chemical, leaching, geochemical, and microstructural analysis was conducted on the samples from each site. Geochemical modeling was also carried out to assess phases for metals that control solubility. The report concluded that all the sampled sites continued to perform well and met their Remedial Action Operations (Passify 2010). The report also affirmed the viability of S/S as an effective long-term treatment, as long as the contaminated materials are known and an effective binder system is developed (Hills, Antemir et al. 2010, Solidification/Stabilization 2011).

2 APPROACH AND METHODOLOGY

The main purpose of this study is the long-term performance evaluation of stabilized sediments, in the state of New Jersey. It will provide insight on the sustainability and practicality of beneficial reuse, as amended dredged materials are considered to be our future construction projects. Over the past twenty years, the state of New Jersey has accepted over 30 million cubic yards of material that have many practical uses. This study was conducted to develop a methodology based on existing studies, reviewing records, and visiting field sites, when necessary. A total of 6 sites in NJ were identified for inclusion in this study and each site had different types of soil, waste, pollution (organic and inorganic), and employed different binder and remediation systems. Table 1 shows the type of contamination, type of site, the remedies, remediation formula and the amount of dredged material transferred to the sites. Table 2 shows additional details about the available sites.

The objective of this report is to facilitate proper dredged material management by providing assistance to governmental entities and project managers. The main questions this study invokes, that needs to be addressed, are as the follows:

(i) What is the evaluation of the long-term performance of stabilized sediment?
(ii) Do geotechnical and chemical properties change over time?
(iii) Are placement criteria still being met at stabilized dredged material sites?

The sites evaluated in this study were located in the states of New Jersey and differed widely in soil type, pollutants present, and remedial treatment of S/S. Placement criteria for each site differed based upon site characteristics, future uses, and the characteristics of the sediment being placed. Significant difficulties were encountered during the process of investigating these sites. Incomplete records, uncooperative site owners/operators, and abandonment of the site were encountered. However, based on the fact that most of the sites have subsequently been redeveloped and are now functioning sites indicates that the SDM was not an impediment to this process.

Table 2 SDM Sites Investigated During this Study

Site ID	Remedial Strategy	Current/Future Use	Past Use
Bellmawr	Landfill Cap/Permeability Control	Retail Residential and Parkland	Mixed of marshland area and commercial
DuPont Graselli	Site Capping	Warehouse, Light Manufacturing , office space---	Industrial/Commercial development
Koppers Coke	Capping / Subsurface Grading	Intermodal Transportation Hub	Manufacture gas, Industrial/Commercial
NL Industries	Capping / Subsurface Grading	Future mixed residential & commercial	Paint pigment manufacturing /Commercial
OENJ Elizabeth	Subsurface Grading	Parking lot	Sanitary Landfill
OENJ Bayonne	Subsurface Grading	Golf course	Non-sanitary landfill

In order to determine the most suitable management practice for the dredged material when preparing a risk assessment, the type and severity of contamination must be assessed (Stollenwerk, Smith et al. 2012). The development of a long term durability assessment for SDM placed at a site, required the identification of a series of 4 tasks that would provide the background needed to determine if the SDM was meeting it design criteria. These tasks are:

Task 1: Investigating site history
Task 2: Identifying potential contamination pathways from SDM and site reconnaissance
Task 3: Identification of beneficial use and required performance criteria
Task 4: Assessment of long term durability of SDM material.

A review of the available data at the sites identified in Table 1. for each of the tasks was conducted. Data gaps were found to exist. These data gaps reduced the ability to develop hypotheses about the general practice of S/S for beneficial reuse. However, the fact that regulatory oversite was reduced or eliminated and redevelopment of most of these sites indicate that on a case by case basis the SDM is not a limiting factor for the construction or other site activities.

2.1 Task 1: Investigating site history

Bellmawr Landfill: The Bellmawr landfill is located south and west of the intersection of NJ Rt. 42 & I-295 with the address of 204 Harding Ave. Bellmawr, NJ 08031. Bellmawr Waterfront Development, LLC was formed with the purpose of investigating the environmental conditions and exploring the feasibility of potential future development. This 150-acre site consists of three areas: former Dewey Blanton Landfill (which was never used as a landfill), Fazzio Deptford landfill and Fazzio Bellmawr landfill. The site is situated within a mixed commercial, residential, and marshland area. Operations started in the 1960s and went on into 1979. The landfill was closed in the 1980s, however and NJDEP remediation of the site was required. As part of this remedial effort, 335,000 cubic yards of dredged sediment was used as a cap on the landfill. The Bellmawr Landfill is currently an undeveloped area owned by the Bellmawr Waterfront Development. The current Plan for the site is a waterfront park and commercial and residential redevelopment.

DuPont Grasselli: The site is located in the industrial area on Tremley Point in the eastern portion of Linden, NJ, on South Wood Ave. The site has been a chemical manufacturing site for over 100 years. Prior to 1928 the Grasseli Chemical Company produced industrial acids at the site. DuPont then purchased the site and produced pesticides there until 1990. The site has significant contamination in the subsurface. The DuPont Grasselli site originally consisted of tidal marshlands that, over time, were reclaimed by placement of fill. The site was capped using in excess of 500,000 cubic yards of SDM. The site is currently mostly vacant with a concrete crushing/recycling operation on the southern portion of the site.

Koppers Coke: This site is located in marshland along the Hackensack River on the Belleville Turnpike and Fishhouse Road in Kearny, Hudson County. The site was the former location of the Koppers Seaboard Coke and By-Products plant. The site processed coal and coal tar into industrial products. The existing site 138 site was slated for redevelopment by the Hudson County Improvement Authority. As part of the redevelopment, the site was capped the site using approximately 2,000,000 cubic yards of SDM. This site redevelopment plan is for a multimodal transportation facility including warehouses and other commercial and light industrial uses.

NL Industries: The site is the former site of Nation Lead Industries. The site was a major paint manufacturing site located in Sayreville, NJ at 1000 Chevalier Ave. During site redevelopment, in excess of 2,000,000 cubic yards of SDM was brought on-site from a variety of sites located throughout NYNJ Harbor. The SDM was stored at the site for several years prior to the recent redevelopment activities during which it has been used for subsurface grading as well as capping of the site. The future use of this site is a large waterfront commercial and residential development.

OENJ Elizabeth: The site, also formerly known as the OENJ Elizabeth landfill, is located at 500 Kapkowski Road, Elizabeth, New Jersey. The 180-acre site was formerly sanitary landfill which was found to have a history of potential "illegal" dumping. Soil borings completed at several locations on this site, strong oil and chemical odors were noted in the soil borings. Redevelopment of the site was completed in the late 1990's. The site was capped with 1,300,000 cubic yards of SDM. The site is currently home to a warehouse, rail road terminal and as a parking lot for the Elizabeth mall.

OENJ Bayonne: The site was a former municipal non-sanitary landfill, locate on Hook Road, Bayonne, NJ. The site is 126 acres located along the lower NY Harbor and Kill Van Kull. The site was capped with 2,000,00 cubic yards of SDM. The site is currently home to a Golf Course.

2.2 Task 2: Identifying potential contamination pathways

Understanding the pathways of aqueous transport of contaminants is necessary to determine the location and mass of contaminants at a given time and predict their migration throughout the site's hydrogeological system. Identifying potential sources of contamination also helps to determine what environmental media can be affected. The potential contamination typically follows the following pathways to soil or water:

<u>Leachate:</u> Leachate generation is considered to be the main drawback for landfilled solid waste and sediment and could be a threat to both surface water and groundwater. The physical, chemical, and biological characteristics of solid wastes (or sediment) may result in the generation of leachate (Raghab, El Meguid et al. 2013). Leachate sometimes includes large amounts of organic contaminants, high concentration of heavy metals, and some hazardous inorganic chemicals. Leachate is generally characterized by high values of COD, pH, ammonia, nitrogen and heavy metals and usually have a strong color and bad odor. At the same time, the leachate's characteristics also vary with respect to its composition and volume, as well as the biodegradable matter present in the leachate (Malina and Pohland 1992, Im, Woo et al. 2001). The S/S process is characterized by two mechanisms for the sequestration of chemical species in the material. Stabilization is the chemical alteration of the contaminant to reduce its mobility. An example of this process is the lower solubility of many metals at high pH. If the metal species is made less

soluble the potential for leaching is reduced. Solidification is the physical alteration of the matrix to reduce the movement of water through the matrix itself. This process is manifest through the hydraulic conductivity of the soil. SDM typically has a hydraulic conductivity similar to that of clay. At SDM placement sites, the leachate may be the result of the SDM or the underlying soils. At most of the sites identified for this study, only SDM that contained less contamination than the pre-placement site was allowed. Therefore, leachate from the SDM was typically not considered an issue. It was instead considered a remedy for the existing soils as a cap.

Surface runoff with erosion: Surface runoff is considered to be a major element of the water cycle and a common pathway for the transport of pollutants. SDM placement sites are required to have standard engineering controls to eliminate or limit the possibility of erosion from the site. After placement the SDM is typically covered via structures, pavement, or a growth medium. The material is not considered a final cover material and should not be an exposed surface. Post-redevelopment, the SDM is considered an engineered cap and should be inspected and maintained in order to reduce the potential for erosion.

Air: Stabilization of sediment with a pozzalon is an exothermic reaction that may drive off water through evaporation. During this process, some contamination in the sediment matrix may volatilize. However, studies have shown that while the concentrations of these chemicals may be elevated during the mixing and placement process, as the material cures or is covered the mass released is insignificant. The primary concern for SDM placement sites is the generation of dust. Dust is usually controlled on the site through the use of water trucks. However, after redevelopment and coving of the SDM it is no longer a concern.

The primary pathway for release that was assessed for the SDM sites during this study was runoff. Although leaching may occur, it could really only be measured through leachate samples. All leachate testing for the sites were geared toward leaching from the pre-filled contaminated site. Since the SDM contained less contamination and did not bring non-preexisting chemicals on to the site leachate analysis was typically not completed.

Currently four of the six sites that were investigated have not been redeveloped (or finished) yet. The Bellmawr Landfill is a vacant site with exposed fill. The original design was for the landfill material to be capped with a gas collection layer, which is then capped with SDM. On top of the SDM is a drainage layer and a topsoil layer. This design eliminated the inflow of rainwater into the SDM and thus eliminated the need to monitor leachate from it. Pictures of the site indicate that it is barren land with weeds over the engineered SDM cap.

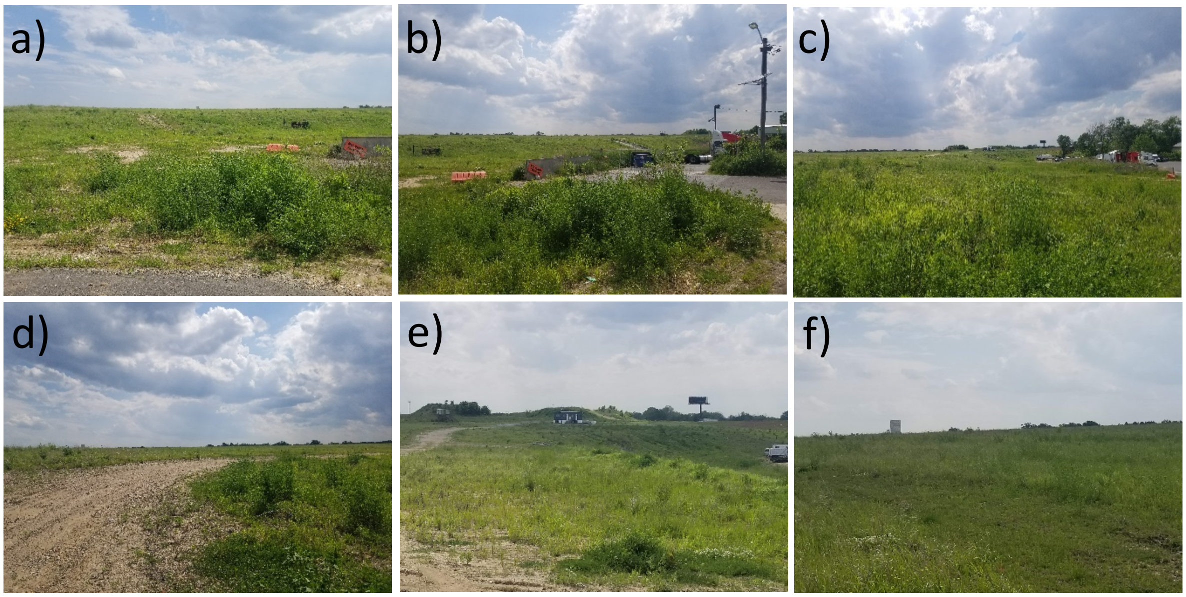

Figure 1 Bellmawr Landfill

Historical manufacturing at the DuPont Grasselli site included the production of sulfuric acid, ammonium thiosulfate, sodium bisulfate, inorganic salts, acids, and organic pesticides. The site has been filled with SDM and is graded for redevelopment above the Base Flood Elevation. Currently the site is dormant. Storm water may be a pathway for the SDM to runoff the site, however the risk is limited.

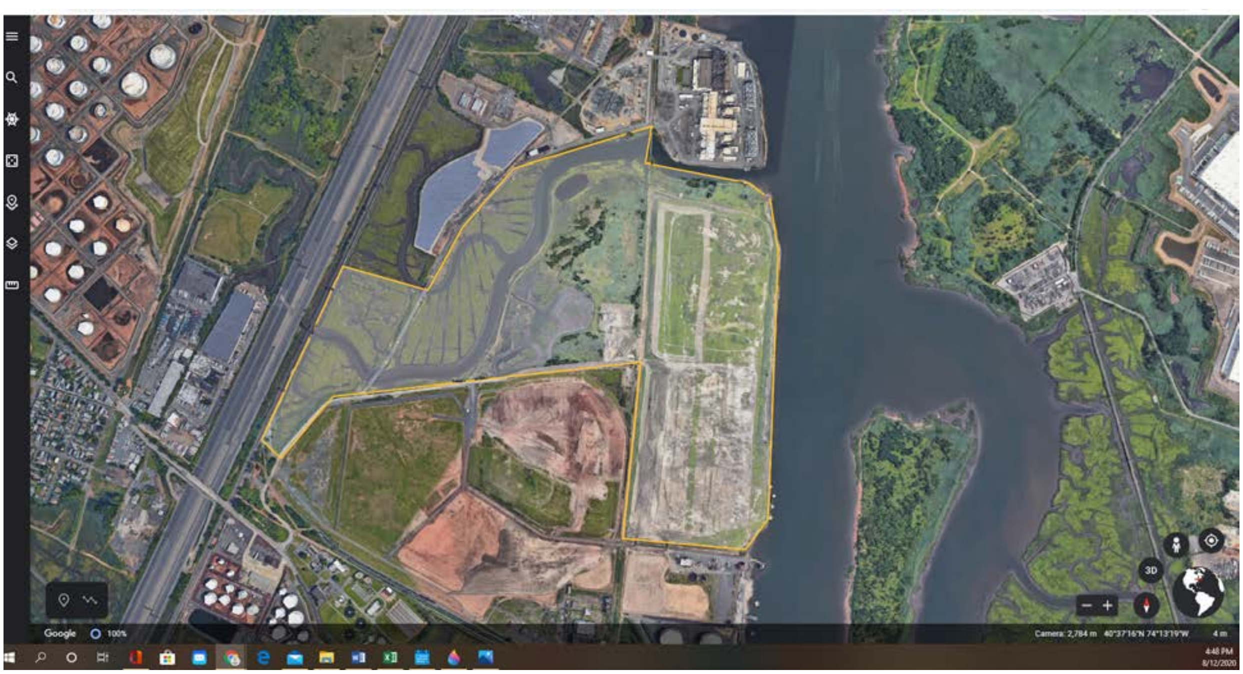

Figure 2 DuPont Grasselli Landfill Site

The Koppers Coke site along the Hackensack River in South Kearny, NJ is currently being redeveloped. Clean Earth Inc. of Hatboro, PA has been receiving and processing dredged sediment from several locations around the region. The site is actively being capped and has the required engineering controls required for an active construction site. The site is surrounded by silt fencing to arrest runoff, and water trucks are used to eliminate dust generation. When complete the redevelopment will cap the SDM with soil, parking lots or structures.

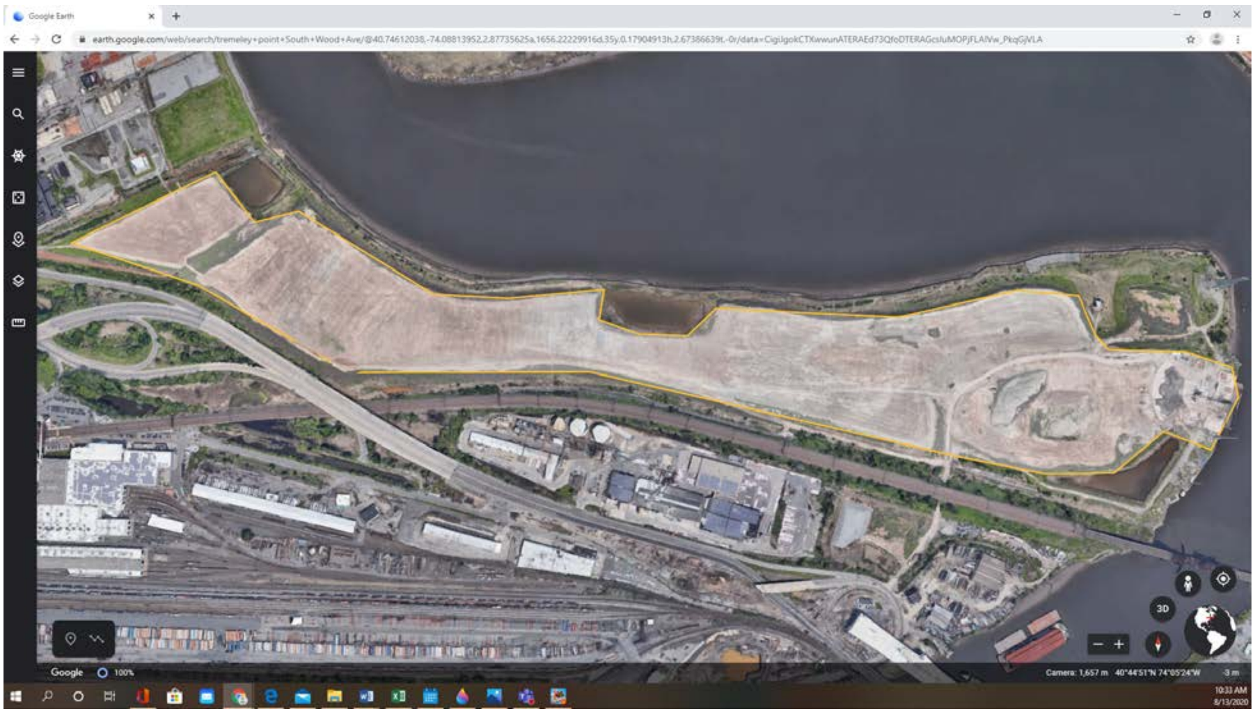

Figure 3 Koppers Coke SDM Placement Site

The NL site along the Raritan is currently under construction for redevelopment. The site is actively being capped and has the required engineering controls required for an active construction site. The site is surrounded by silt fencing to arrest runoff, and water trucks are used to eliminate dust generation. The SDM that was imported to the site was processed off-site then stockpiled at the site for a period of years. Site investigation indicates that the SDM that was brought to the site meets all the environmental criteria required, however the material's geotechnical characteristics and water retention characteristics have been identified as a potential issue. During rain events the SDM has been observed to absorb water and become muddy and unworkable. This is not typical of SDM and the issue has been investigated.

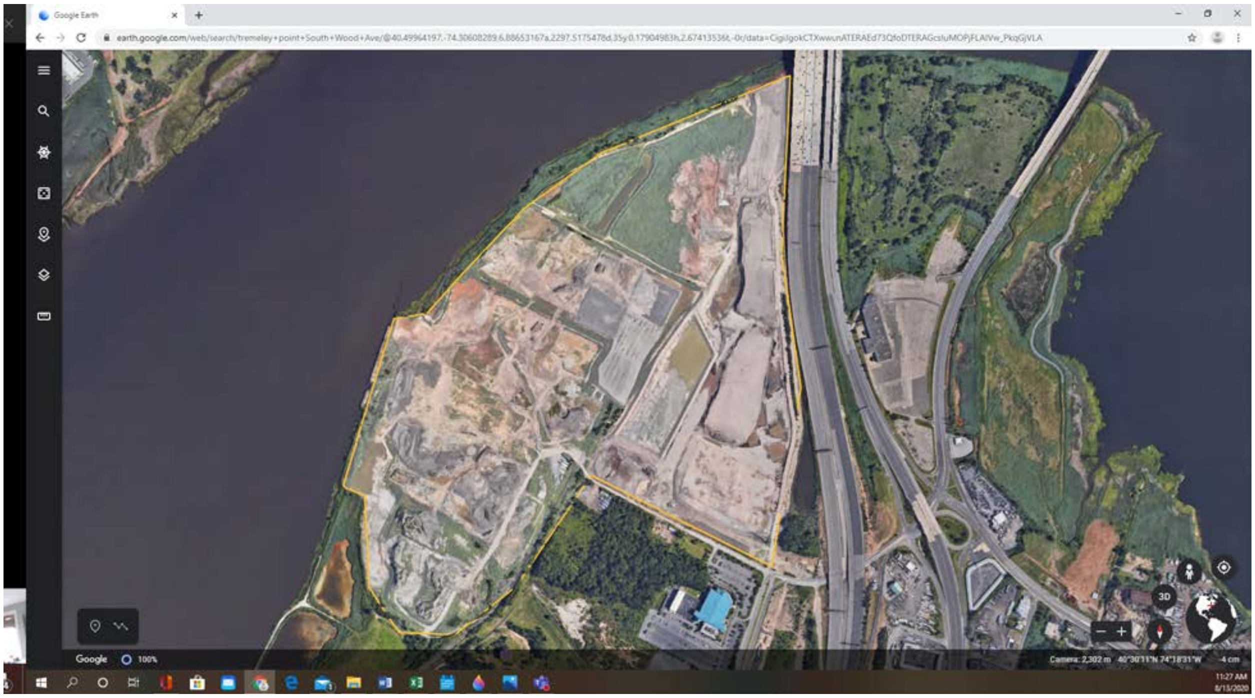

Figure 4 National Lead SDM Placement Site

The OENJ Elizabeth SDM placement site was filled in the late 1990's and subsequently developed as part of the Jersey Gardens Mall development. The entire area has been paved and there are few, if any pathways for releases from the site. This development has been successfully in use since construction and has never had any environmental issues. The only issue that has been observed was differential consolidation was observed in the IKEA parking lot, although it was never discovered whether this was due to the SDM or the landfill underneath. This issue was resolved during periodic maintenance.

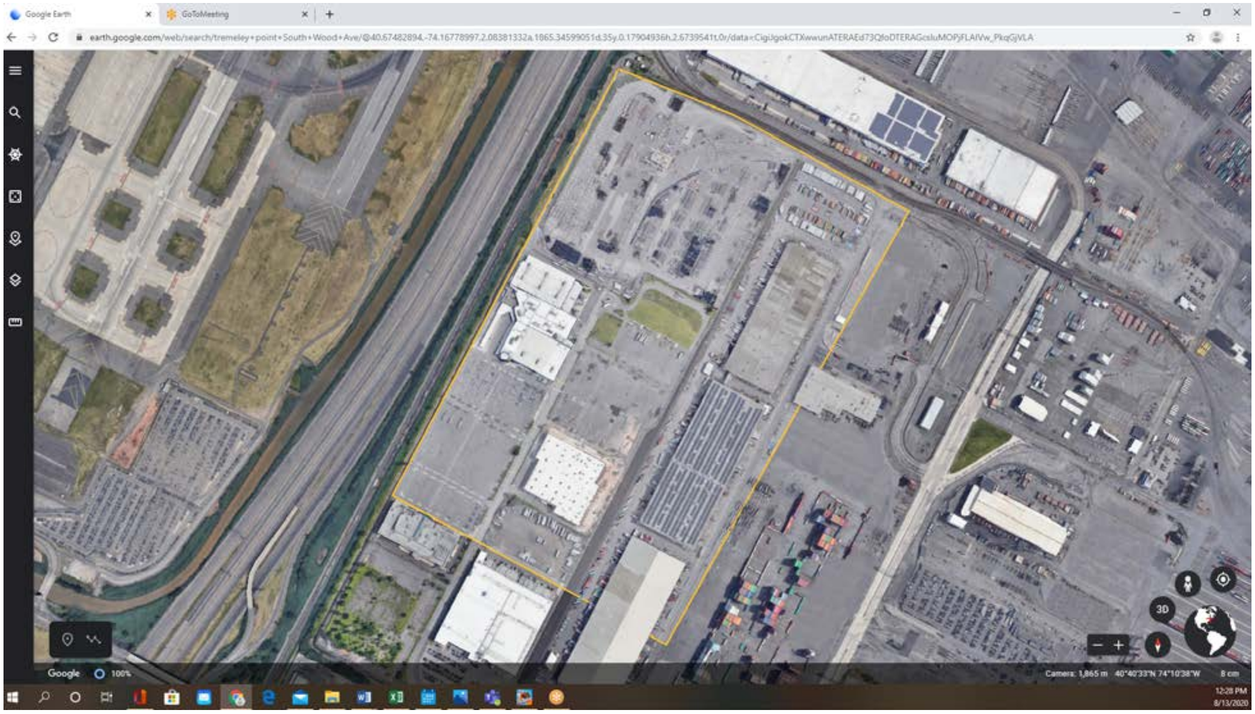

Figure 5 OENJ Elizabeth SDM Placement Site

The OENJ site was a former municipal non-sanitary landfill located in Bayonne, NJ. The site was filled with SDM for landscaping and capping. The site was redeveloped into the Bayonne Golf Club. The course has no trees that could rupture the cap and no environmental issues have occurred.

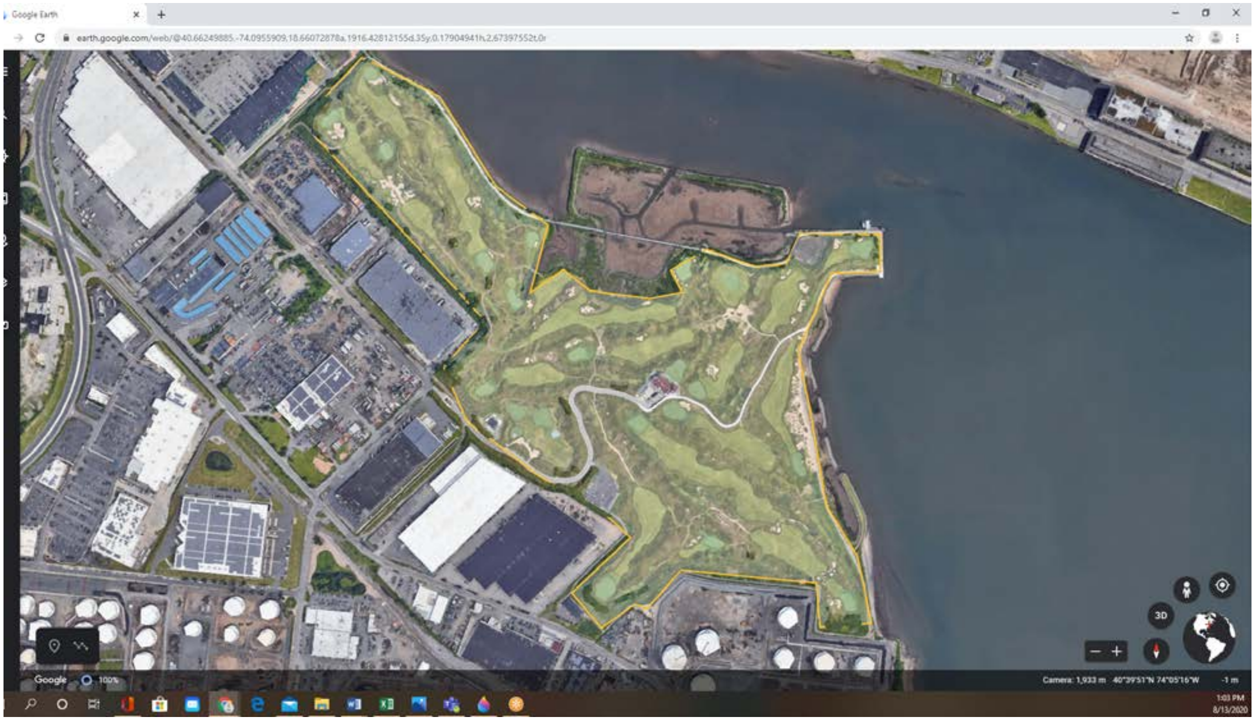

Figure 6 OENJ Bayonne SDM Placement Site

2.3 TASK 3: IDENTIFICATION OF BENEFICIAL USE AND SDM PROCESSING STRATEGY

The determination of the success or failure of SDM in the long term, years after placement, are highly dependent upon the actual beneficial use. Environmental performance criteria are relatively standard, based upon leaching analysis compared to Impact to Groundwater Standards. There have not been any environmental failures at any of the sites investigated during this study. Geotechnical performance criteria for SDM sites are site specific and based upon the beneficial use strategy. For uses such as fill for landscaping at a golf course, the geotechnical requirements are limited, however for locations such at Koppers Coke, all fill was required to achieve 2 tons per square foot with a plate load test. Each of the SDM sites had a similar strategy for processing of the material. They were stabilized with Portland Cement at a mix ratio of 8% by wet weight.

Table 3 SDM Placement Site Processing Strategy.

Site ID	Beneficial Use	Processing Strategy
Bellmawr	Capping	Stabilization 8% Portland Cement
DuPont Graselli	Capping	Stabilization 8% Portland Cement
Koppers Coke	Capping / Fill	Stabilization 6-12% Portland Cement (Pug Mill)

NL Industries	Capping / Fill	Stabilization 8% Portland Cement (In-Barge Stabilization)
OENJ Elizabeth	Fill	Stabilization 8% Portland Cement (Pug Mill)
OENJ Bayonne	Fill	Stabilization 8% Portland Cement (Pug Mill)

2.4 Task 4: Assessment of long term durability of SDM material.

In order to investigate the long-term durability of dredged material, the treatment process should be considered with respect to the desired beneficial use of the SDM. S/S is the use of a pozzalonic additive to react constituents in the dredged material to provide desired chemical and physical properties. Chemically, S/S is completed to restrict the movement of contaminant contained within the sediment matrix. Physically, S/S is completed to restrict contaminant migration via reductions in hydraulic conductivity and to produce a material that has the required geotechnical strength to facilitate site use.

The chemical characteristics of the SDM are well established prior to placement at the beneficial reuse site. Dredging is a permitted process and a dredger must identify, as part of obtaining a permit, the ultimate disposition of the dredge material. All SDM placement sites are also permitted and must comply with the terms of their permit. The placement site acceptance criteria are based upon the site setting and takes into account any potential risks to the environment from fugitive chemical releases. In addition, most of these sites are Brownfield sites and are typically impacted to a far greater extent than the SDM they receive. In fact, the SDM is often used as part of the remedial strategy for capping of contaminated materials at the site. Investigations made into the site revealed no violations resulting from chemical breakdown of the SDM cap. Since these sites are Brownfields, the research team reached out to the Licensed Site Responsible Party (LSRP)s. Unfortunately, the LSRPs informed us that the sites were in compliance, but would not furnish measurements for ongoing remedial actions. It was also stressed to our researchers that the SDM caps were installed as part of the remedy, and was not the issue that resulted in the remedial investigation/actions.

The geotechnical performance of the material was also investigated. Though no issues associated with the performance were documented through our literature search. Conversation with site contractors did identify small issues that affected their operations after site redevelopment. First, consolidation did occur at the Jersey Gardens Mall (OENJ Elizabeth), however it was never determined if this was a result of the SDM or the underlying landfill. Second, the water retention characteristics of a portion of the stabilized material brought to the National Lead site made it difficult to use as geotechnical fill during the redevelopment of the site. Samples of the material were observed by Rutgers personnel to consist of mud surrounding a harder nucleus. The material has the appearance of beads of sediment. When broken, it can be observed that the nucleus of these beads is solid cured Portland cement. It has been hypothesized that this occurred during the stabilization process when the Portland cement and sediment mixture were not sufficiently mixed to completely incorporate the Portland cement into the sediment.

3 CONCLUSIONS/RECOMMENDATIONS

The investigation that was conducted into the long term durability of SDM involved an in-depth review of all available records regarding six SDM placement sites as well as site visit and interviews. The findings were that since these sites were capped or filled with SDM, there has been no evidence of chemical releases from the SDM at any of the sites and the geotechnical requirements of the material were generally met. The only exception took place at the National Lead site, however it is believed that the initial mixing during stabilization is probably the reason. As a result it is concluded that based on the six sites that were studied the SDM does not break down or fail to maintain its design function. Further investigation of this material should include laboratory studies that use an accelerated testing regime to determine what conditions could result in material failure.

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