Contaminated Sediments at Navy Facilities: Policy, Guidance, and Characterization

Addressing contaminated sediments at Naval facilities presents technical and managerial challenges. The state of the science is still evolving, as are the environmental regulations that apply to contaminated sediments. The Chief of Naval Operations (CNO) promulgated the "Policy on Sediment Site Investigation and Response Action" (CNO, 2002) to address ongoing sediment policy issues relative to the Navy’s cleanup program. Likewise, Naval Facilities Engineering Command (NAVFAC) developed the "Implementation Guide for Assessing and Managing Contaminated Sediments at Navy Facilities" (NAVFAC, 2002) to provide sediment-specific technical information for Remedial Project Managers (RPMs) and their technical support responsible for contaminated sediment sites, and to assist in streamlining the decision-making process. The implementation guide encourages a consistent and effective approach to site characterization, risk assessment, remedial option evaluation, long-term monitoring, and site closeout. The implementation guide is consistent with various Navy policies related to the Installation Restoration (IR) and Base Realignment and Closure (BRAC) programs and with the substantive requirements of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and existing United States Environmental Protection Agency (U.S. EPA) guidance.

This TechData Sheet describes current Navy policy toward sediment cleanup efforts, and focuses on the technical considerations and decision-making framework contained in the NAVFAC implementation guide.

NAVY POLICY AND GUIDANCE DEVELOPMENT

Contaminants enter sediments from a variety of point sources such as spills, industrial or municipal discharges, and outfalls, as well as nonpoint sources such as runoff; atmospheric fallout; and ship waste or bilge waste. This is depicted in Figure 1. Major sediment contaminants are nonvolatile and insoluble compounds that persist in the environment. The U.S. EPA (1997) estimates that 6 to 12% of U.S. sediment is contaminated. Approximately 2,800 fish advisories are currently in force nationwide (U.S. EPA, 2001).

In a 1993 survey of Navy facilities, 94% of the respondents reported the presence of at least one contaminant of potential concern in sediments. The most common contaminants reported were metals (76%), PCBs (72%), other hydrocarbons (72%), pesticides (55%), and fuels (45%). Based on the 1993 survey, it was estimated that the cost-to-complete would exceed $500 million for contaminated sediment at IR and BRAC sites. More recent information indicates that costs-to-complete could be more than twice that figure.

The regulatory and policy framework surrounding sediment site investigation and cleanup can be challenging. Sediment investigations are often more complex than terrestrial investigations for a variety of reasons, including the inherently dynamic sediment ecosystem, contaminant mobility, and the variety of potential exposure pathways. There is also a lack of promulgated sediment quality criteria, incomplete knowledge and understanding of aquatic food webs, and lack of published risk-based threshold data (e.g., toxicity reference values) for many chemicals of potential concern. Additionally, sediments commonly require specialized methods for sampling, analysis, and remediation. RPMs responsible for sediment sites must make informed, site-specific decisions that reflect an understanding of the Federal, State, and local regulations and requirements, and that balance risk reduction, public benefit, and costs.

Figure 1. Plan view of aquatic setting. Modified from http://www.epa.gov/owow/oceans/factsheets/fac5.html

One important Navy document is CNO's "Policy on Sediment Site Investigation and Response Action" (CNO, 2002), which outlines guiding principles to be followed for all sediment investigations. The CNO policy statements are:
1. All sources shall be identified to determine if the Navy is solely responsible for the contamination.
2. All investigations shall primarily be linked to a specific Navy CERCLA/RCRA site.
3. All sediment investigations and response actions shall be consistent with Navy policies on risk assessment and background chemical levels.
4. Sediment cleanup goals shall be developed based on site-specific information and shall be risk-based.
5. The Navy shall not clean up contamination from a non-Navy source where the Navy has not contributed to the risk in sediments. The Navy will not clean up a site before the source is contained. Any potential re-contamination by non-Navy sources shall be documented.
6. A monitoring plan with exit strategies shall be developed before collecting the first monitoring sample.

The NAVFAC implementation guide is organized into four principal sections: Introduction, Site Characterization, Risk Assessment, and Remediation; followed by a glossary and references. Hyperlinks throughout the document connect the reader to related Web sites and documents. A summary of the Site Characterization, Risk Assessment, and Sediment Remedial Alternative Evaluation sections follows.

**Sediment Site Characterization**

This section of the NAVFAC implementation guide presents an overview of the site characterization process relative to sediment investigations, including planning considerations, developing a CSM, identifying sources, defining the nature and extent of contamination, and characterizing contaminant fate and transport. Figure 2 shows a typical food web model with the ecological processes evaluated during the sediment site characterization. This section also identifies important physical and chemical data that should be collected as part of a sediment investigation, with an emphasis on coordinating data collection for all aspects of the investigation (site characterization, risk assessment, and evaluation of remedial alternatives). An overview of sample design and sample collection methods and equipment is also presented.

**Contaminant Fate and Transport**

Fate and transport refers to the processes responsible for the movement, partitioning, transformation, or degradation of contaminants in the environment. The main processes controlling the transfer of contaminants in the aquatic environment include: (1) hydrodynamic transport, (2) sediment deposition and resuspension, (3) sediment burial, and (4) chemical and biological transformation processes. Contaminants enter the aquatic environment primarily sorbed to particles; therefore, particle size and settling velocity impact the fate of sorbed contaminants in the aquatic environment. Most organic contaminants found in sediments are insoluble or only sparingly soluble. Soluble contaminants and volatile...
contaminants are easily diluted in the water column and
do not concentrate in sediments.

In contrast to terrestrial sites, aquatic (sediment) sites
almost always have a complex mixture of contaminants
from multiple point and nonpoint sources that have been
integrated by the above processes, transported, and
deposited away from their origins. Because of the
dynamic nature of the aquatic environment, contaminants
can potentially migrate both on and off Navy property.
Compiling existing regional data can help distinguish
between Navy-related contamination and contaminant
loading from background and non-Navy sources. Fate
and transport studies can range in complexity from
cursory to involved, and should be designed appro-
priately for the scale of the site.

Sediment Sampling Methods
The implementation guide provides an overview of
advanced sediment sample collection methods including
the applicability of different sediment sampling methods.
Figure 3 shows a benthic flux sampling device, which
measures diffusional fluxes of contaminants between
sediment and overlying water. Surface sediment samples
are usually collected with a grab sampler such as a box
corer, an Eckman grab, a Ponar grab, or a Van Veen
grab. Sediment cores can be collecting using gravity
corers or Vibracore. Rapid sediment characterization
(RSC) tools are field transportable tools that provide
rapid measurements of chemical, biological, and physical
characterization parameters. Examples of RSC tools
include x-ray fluorescence for metals; immunoassay for
PAHs, PCBs, and pesticides; and the QwikSed bioassay
for biological effects. RSC tools are encouraged in Navy
policy and guidance to:

- Optimize field sampling design.
- Increase the probability of successful, high impact
  sampling.
- Cost-effectively use high-quality laboratory
  analytics in combination with RSC tools.
- Provide the ability to fill gaps and reduce
  uncertainty at several steps in the Remedial
  Investigation/Feasibility Study (RI/FS) process
  without the high cost of traditional sampling
  methods.
- Map contaminated sediment volumes more
  efficiently to reduce remediation cost.

Site Characterization Parameters
The implementation guide provides a concise summary
of the key physical, chemical, and biological parameters
pertinent to sediment studies, describes the importance
and relevance of each item, and suggests appropriate
analytical and test methods.

Physical: Physical characteristics must be considered in
sediment site investigations because they can influence
contaminant loading, affect bioavailability, and introduce
factors that confound test results. Additionally, geotechni-
cal data are needed to evaluate sediment-engineering
properties for remedial design. Once measured in sedi-
ments, physical characteristics can be used to better
understand contaminant distributions and sources, toxicity
results, and local hydrodynamics. Primary physical
parameters include total organic carbon, sediment grain
size, ammonia, sulfide, acid volatile sulfide, salinity, and
geotechnical data. The recommended analytical and test
methods for these physical parameters are summarized in
the implementation guide.

Figure 3. Benthic flux sampling device.

Chemical: Chemical parameters include metals,
chlorinated pesticides, PAHs, PCBs, and organotins.
Appropriate analytical methods recommended by the
Navy are summarized in the guide. Chemical parameters
are used to assess site risk, but also can be useful in
source identification (e.g., distinguishing between Navy
and non-Navy causes of contamination).

Forensic chemistry can be used to evaluate contaminant
loading or identify a potential contaminant source. For
example, anthropogenic metal contamination can be dis-
tinguished from naturally occurring background levels
based on the ratio of trace metals to either aluminum or
iron in a given sample. Other methods in chemical finger-
printing can be used to identify sources of petroleum and
chlorinated hydrocarbon contaminants (e.g., PAHs,
PCBs). The ability to “fingerprint” a sample depends on
several conditions including: (1) the ability to resolve
chemicals from different geological sources, (2) relative
state of weathering (or aging) of organic contaminants,
(3) presence of specific product additives and refinery
process signatures (for petroleum-related contamination),
and (4) availability of reference source materials.

Biological: Biological data are not appropriate in initial
characterization efforts at Navy sediment sites. However,
for the baseline risk assessment, biological test samples
should be collected with the relevant chemical and
physical samples. The implementation guide discusses
the most common types of biological data collected in
support of sediment site investigations including benthic
bioassays, bioaccumulation studies, and benthic community characterization.

**Risk Assessment**

This section of the NAVFAC implementation guide presents step-by-step procedures for conducting ecological and human health risk assessments at sediment sites within the Navy’s tiered framework. Elements within the ecological and human health risk assessment framework that are unique to sediment investigations are identified. For ecological assessments, the key differences for sediment sites stem primarily from the use of aquatic assessment and measurement endpoints, the data collection and analytical methods used for aquatic media, and issues concerning contaminant exposure and fate and transport in water bodies. For human health assessments, additional exposure routes must be considered such as potential exposures via surface water or sediment contact and ingestion of fish or shellfish. The guide also outlines effective approaches to complete fish tissue and fish consumption studies as part of the risk assessment process. Figure 4 provides an example of the aquatic environment being studied for these assessments.

**CONCLUSION**

Contaminated sediment remediation is a relatively new and rapidly evolving field, and comparatively few clean-up technologies have been applied at sediment sites to date. Challenges to the successful selection and implementation of remedies at sediment sites include the following: (1) presumptive remedies for contaminated sediments have not been identified; (2) development and verification of cleanup goals is difficult; (3) logistical challenges can include lack of visibility, interference by currents and waves, contaminant release during cleanup, or accessibility issues; and (4) limited data is available on long-term effectiveness of remedies. The CNO’s *Policy on Sediment Site Investigation and Response Action* addresses ongoing sediment policy issues, and the NAVFAC *Implementation Guide* addresses planning considerations, determination of site-specific cleanup levels, and determination of sediment remediation boundaries and volume. Remedial options, including natural recovery, in situ capping, and dredging are covered, along with monitoring considerations and sediment management issues. The short and long-term risks and liabilities associated with each type of remedial action are discussed.

**REFERENCES**


**FOR FURTHER INFORMATION**

NAVFAC HQ at Ph. (202) 685-0096  
EFANE at Ph. (610) 595-0567 ext. 188  
SSC San Diego at Ph. (619) 553-5255  
NFESC at Ph. (805) 982-4798  
LANTDIV at Ph. (757) 322-4768  
SOUTHDIV at Ph. (843) 820-7324  
SWDIV at Ph. (619) 532-2584