



Standard Guide for Packaging and Shipping Environmental Samples for Laboratory Analysis¹

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1. Scope

1.1 This standard provides guidance on the selection of procedures for proper packaging and shipment of environmental samples to the laboratory for analysis to ensure compliance with appropriate regulatory programs and protection of sample integrity during shipment.

1.2 This standard does not address transport of hazardous wastes for disposal purposes.

1.3 This standard does not address the selection of parameter-specific sample bottles or containers.

1.4 This guide offers an organized collection of information or a series of options and does not recommend a specific course of action. This guide cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this guide may be applicable in all circumstances. This guide is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this guide be applied without consideration of the many unique aspects of a project. The word “standard” in the title of this guide means only that the guide has been approved through the ASTM consensus process.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory requirements prior to use.*

2. Referenced Documents

2.1 ASTM Standards:

- D 653 Terminology Relating to Soil, Rock and Contained Fluids²
- D 4220 Practice for Preserving and Transporting Soil Samples²
- D 4840 Guide for Sample Chain of Custody Procedure²

¹ This guide is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.21 on Ground Water and Vadose Zone Investigations.

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² *Annual Book of ASTM Standards*, Vol 04.08.

- D 5079 Practices for Preserving and Transporting Rock Core Samples²
- D 5903 Guide for Planning and Preparing for a Ground-Water Sampling Event³
- D 6089 Guide for Documenting a Ground-Water Sampling Event³
- D 6517 Practice for Field Preservation of Ground-Water Samples²

2.2 Shipping Regulations:

- International Air Transport Association (IATA) Dangerous Goods Regulations, 43rd Edition, January 2002
- International Atomic Energy Agency (IAEA) Regulations for the Safe Transport of Radioactive Material, Section 10, Publication IAEA TS-R-1
- International Civil Aviation Organization (ICAO) Technical Instructions for the Safe Transport of Dangerous Goods by Air, Document #9284-AN/905
- U.S. Government Printing Office, Title 40 Code of Federal Regulations Resource Conservation and Recovery Act (RCRA), Part 261
- U.S. Government Printing Office, Title 49 Code of Federal Regulations Transportation (DOT), Parts 170-174
- U.S. Postal Service, Hazardous, Restricted and Perishable Mail USPS Publication 52

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 *carrier*—a commercial company that is responsible for the actual shipment of environmental samples from the point of sample receipt from the shipper to the sample’s final destination.

3.1.2 *dangerous goods*—those goods that meet the criteria of one or more of nine United Nations (UN) hazard classes and, where applicable, one of three UN packaging groups according to the provisions of shipping regulations.

3.1.3 *environmental sample*—containerized liquids, solids or gases that are collected for the purpose of laboratory analysis.

³ *Annual Book of ASTM Standards*, Vol 04.09.

3.1.4 *inner packaging*—packaging for which an outer package is required for transport (for example, a sample bottle or container).

3.1.5 *outer packaging*—the outer protection of a composite or combination packaging together with any absorbent materials, cushioning and any other components necessary to contain and protect sample bottles or inner packaging.

3.1.6 *shipper*—the person who actually packages and presents environmental samples to a commercial carrier for shipment or who personally transports samples. The shipper is commonly the person who collected the environmental samples.

3.1.7 *shipping*—the commercial or private transport of environmental samples via highway, rail, vessel or aircraft.

4. Significance and Use

4.1 This standard provides guidance in determining the most appropriate procedures for packaging and shipping environmental samples. Use of this guide by personnel involved in packaging and shipping environmental samples will facilitate safe, effective and compliant procedures.

5. Regulatory Requirements

5.1 The shipment of many environmental samples falls under the jurisdiction of national and standardized international regulations whenever samples exhibit one or more properties that classify the samples as being dangerous or hazardous. Not all environmental samples, however, satisfy the criteria for being classified as dangerous or hazardous substances. These samples can be packaged and shipped as non-regulated or non-hazardous environmental samples.

5.2 It is the shipper’s responsibility to determine which regulations apply to the environmental samples requiring shipment. This determination must be made prior to sample collection to ensure compliance with shipping regulations at the conclusion of sample collection. The primary sources of shipping regulations that can apply to environmental samples include the U.S. Department of Transportation (DOT), the International Air Transport Association (IATA), and the U.S. Postal Service (USPS). DOT regulations govern transport of samples by water, rail, roadway and air; IATA regulations govern air transport of samples; USPS regulates both ground and air delivery of samples through the U.S. Postal System. Other agencies such as the U.S. Department of Agriculture (USDA) (restrictions on interstate shipment of soil samples to prevent the spread of biological contaminants), The International Atomic Energy Agency (IAEA) (transport of radioactive materials by air), the International Civil Aviation Organization (ICAO) (shipment of the dangerous goods by air). The International Maritime Dangerous Goods Code (shipment by vessel) may also need to be considered. Sample shippers must also be aware of the potential for restrictions on shipping samples at both the state and local levels. Shippers should contact state and local agencies to determine any shipping restrictions.

5.3 Should dangerous or hazardous samples be shipped using methods not in full compliance with applicable regulatory requirements, the following penalties can be assessed to the shipper:

5.3.1 Refusal to deliver the environmental samples to their intended destination, which can result in sample integrity being compromised, chain-of-custody being broken, or sample holding times being exceeded;

5.3.2 Assessment of financial penalties which can be severe; and/or

5.3.3 Imprisonment for blatant illegal shipment of dangerous or hazardous substances.

6. Procedures for Packaging and Shipping Environmental Samples

6.1 *Planning*—As indicated in Guide D 5903, the Sampling and Analysis Plan (SAP) for a project will specify the number of samples to be collected for each medium being sampled (for example, soil, ground-water, surface water, soil gas, sediment and corresponding quality control samples). This SAP will also include a discussion on the need to plan for the appropriate number, size(s), and type(s) of outer packaging based on the number and sizes of sample containers to be filled and to plan for adequate space in outer packaging to accommodate inner packing materials and temperature controls. The SAP will specify the analyses to be performed on each sample and should also indicate the type of sample bottle or container and volume required for each analyte. The SAP should also provide guidance on selection of the methods for sample packaging and shipment of samples to the laboratory for analysis when dangerous or hazardous samples are anticipated.

6.2 *Regulatory Responsibilities of the Shipper*—The sample shipper is responsible for ensuring that all environmental samples are packaged, labeled, and marked in a manner that is consistent with applicable shipping regulations. Failure to do so puts the shipper at risk of the penalties discussed in 5.3.

6.3 *Determination of Dangerous or Hazardous Properties of Environmental Samples:*

6.3.1 Prior to collection of environmental samples, it is necessary to determine the hazard class of a sample. If this is unknown, the shipper must use best professional judgment to determine the potential for samples to exhibit one or more hazardous characteristics (for example, through background research review, interviews and review of purchasing and disposal records) and to determine the appropriate degree of danger associated with those hazardous properties as defined by applicable shipping regulations (see Note 1). Table 1 summarizes the nine United Nations (UN) hazard classes that

TABLE 1 Summary of United Nations Hazard Classes

Class 1	Explosives
Class 2	Gases
Class 3	Flammable Liquids
Class 4	Flammable Solids; Substances Liable to Spontaneous Combustion; Substances Which, in Contact with Water, Emit Flammable Gases (for example, soil sample contaminated with high concentrations of gasoline released from an underground storage tank)
Class 5	Oxidizing Substances and Organic Peroxide
Class 6	Toxic and Infectious Substances (for example, samples of refuse collected from a solid waste landfill)
Class 7	Radioactive Material
Class 8	Corrosives (for example, nitric acid used for preservation of some ground-water samples) (see Note 2)
Class 9	Miscellaneous Dangerous Goods

are defined within shipping regulations and provides three examples of environmental samples that might meet the criteria of a given hazard class. Table 2 summarizes the degree of hazard associated with dangerous goods being shipped as defined by applicable shipping regulations.

NOTE 1—Dangerous or hazardous properties of environmental samples are as defined specifically by shipping regulations. Definitions developed for use under other regulatory programs may be substantially different and are not applicable. For example, a corrosive liquid under IATA definition is “a substance which, in the event of leakage, can cause severe damage by chemical action when in contact with living tissue or can materially damage other freight or the means of transportation.” This is determined through a series of intact skin tissue exposure tests and/or corrosive tests on steel or aluminum for defined exposure periods. Under the Resource Conservation and Recovery Act (RCRA), a corrosive liquid is defined as a liquid with a pH less than or equal to 2 or greater than or equal to 12.5, as determined by a pH meter using Method 9090.

NOTE 2—In a letter dated April 11, 1979, the Associate Director for Hazardous Materials Regulation of the Research and Special Programs Administration granted exception to the DOT hazardous materials regulations for water samples containing the corrosives: hydrochloric acid, mercuric chloride, nitric acid, sulfuric acid, sodium hydroxide and phosphoric acid. The listed corrosives include the preservatives commonly used in water samples. This exception was revalidated in a letter issued on December 13, 1993 and again in a letter dated February 14, 1997. This exception may not apply in other shipping regulations.

6.3.1.1 When the actual hazard class of a sample is unknown, the most conservative packaging group possible for the chosen shipping name must be used. Refer to 6.4.1 for guidance on choosing the appropriate shipping name.

6.3.2 It is possible that environmental samples may not exhibit a dangerous or hazardous property and, as such, may be packaged and shipped as a non-regulated sample using methods described in 6.5 and 6.6. Other packaging and shipping guidance is provided in Practices D 4220, D 5079, and D 6517.

6.3.3 The shipper must make the determination of sample hazard prior to collection to ensure that an appropriate carrier has been selected to transport samples to the laboratory and to ensure that appropriate packaging materials are available in the field at the time of sample preparation for shipping.

6.4 *Determination of Proper Shipping Name and UN Number for Dangerous or Hazardous Samples:*

6.4.1 Once the shipper has determined that an environmental sample does or will likely exhibit one or more hazardous characteristics, the shipper must select the “proper shipping name” for the sample as defined by the regulations under which the sample is to be shipped (see Table 3). These shipping names are standard names used in the shipping industry to identify the dangerous article or substance on the outside of the package and on the “Shipper’s Declaration for Dangerous Goods” and are not names created at random by the shipper. To determine the proper shipping name for each environmental sample, the shipper must refer to the shipping regulations that will be followed directly. It is possible for there to be more than one shipping name. The selected shipping name must accurately

TABLE 3 Examples of Proper Shipping Names and Associated UN Numbers

Proper Shipping Name/ Description	UN Number	Example of Environmental Sample
Flammable solid, organic, n.o.s.	1325	Soil sample saturated with gasoline
Nitric acid	2031	Sample preservative that is other than red fuming, with 70 % or less, but more than 20 % nitric acid
Refrigerant gas, n.o.s. (Tetrafluoromethane, Trifluoromethane)	1078	Surface water sample containing mixture of Freon 14 [®] and Freon 23 [®]

rately reflect the chemical, physical or biological characteristics of the sample being shipped and must not include a Trade name.

6.4.2 When selecting the proper shipping name, the shipper must consider:

6.4.2.1 The dangerous or hazardous property of the sample,

6.4.2.2 If the sample is classified as a solid (for example, soil or sediment), liquid (for example, ground-water or surface water) or gas (for example, soil gas or atmospheric air),

6.4.2.3 The anticipated or known contaminant(s) contained in the sample,

6.4.2.4 Whether the contaminant is present in a pure form or a mixture, and

6.4.2.5 The preferred method of sample shipment (for example, ground transportation versus overnight air transportation).

6.4.3 Once selected, the proper shipping name is used by the shipper to obtain the following information from the appropriate shipping regulations:

6.4.3.1 The corresponding UN number,

6.4.3.2 Correct sample packaging (inner and outer packaging),

6.4.3.3 Required package labels and markings,

6.4.3.4 Restrictions on sample volumes per package,

6.4.3.5 Applicable exceptions for small quantity shipments (see Note 3), and

6.4.3.6 Available shipping options (for example, passenger versus cargo aircraft).

NOTE 3—In some cases, very small quantities of dangerous goods may be transported in such a manner that they may be excepted from the marking, labeling and documentation requirements of dangerous or hazardous materials. Actual definitions of excepted small quantities vary by hazard class, carrier and, in some circumstances, by state. Typically, shipments under these exceptions do require the use of DOT or IATA accepted packaging, and the package must be appropriately marked and labeled as specified by the regulations being followed. For example, small quantity exceptions exist for corrosive liquids (Class 8, Packing Groups II and III) which can be applied when shipping vials, ampoules or pre-preserved bottles containing nitric acid preservatives to the field.

6.5 *Selection of Shipping Method:*

6.5.1 Once the hazardous or dangerous nature of an environmental sample has been determined by the shipper, and the shipping name has been selected, the method of shipment must be determined. For both non-regulated and hazardous or dangerous environmental samples, the following sample options must be evaluated by the shipper for applicability and compliance with shipping regulations:

TABLE 2 Summary of Packing Groups By Hazard Level

Packing Group I—High Danger
Packing Group II—Medium Danger
Packing Group III—Low Danger

6.5.1.1 Direct sample delivery by the sampling team to the laboratory,

6.5.1.2 Sample pickup and subsequent delivery by a laboratory-provided courier,

6.5.1.3 Commercial overnight carriers,

6.5.1.4 Public transportation systems (for example, public buses, ferries, passenger aircraft),

6.5.1.5 Commercial ground transportation carriers, and

6.5.1.6 U.S. Postal Service delivery options (for example, overnight, three-day etc.).

6.5.2 Each method presented in 6.5.1 must be evaluated with regard to the:

6.5.2.1 Potential for sample breakage and loss due to carrier handling practices,

6.5.2.2 Potential for sample tampering during shipment,

6.5.2.3 Sample delivery time versus sample holding time,

6.5.2.4 Ability to maintain sample chain-of-custody procedures,

6.5.2.5 Compliance with regulatory requirements for dangerous or hazardous samples,

6.5.2.6 Existence of any regulatory restrictions, limitations or exceptions

6.5.2.7 Carrier-specific variances on shipping regulations (see Note 4), and

6.5.2.8 Locations of drop-off stations accepting dangerous or hazardous samples for shipment.

6.6 *Selection of Proper Sample Packaging and Packing Procedures:*

6.6.1 *Packaging Non-Regulated or Non-Hazardous Samples for Shipment*—The shipper is responsible for all aspects of the packaging of samples for shipment to the laboratory. In cases where samples have been determined to be non-hazardous or unregulated, samples should be packaged in a manner that will protect both the physical and chemical integrity of the samples during transport to the laboratory as described in Practices D 4220, D 5079, D 6517, and Guide D 5903. Sample packaging should be selected with the following considerations in mind:

6.6.1.1 *Total Weight of the Final Package Once Filled With Samples*—The weight of the empty package should be such that, once filled with samples, the final package weight will not be so great that it will be too difficult to move and may exceed standard per-package weight limits for shipping.

NOTE 4—The shipper must be aware that commercial sample carriers must comply with all shipping regulations, but that carriers are permitted to develop and enforce company-wide variations from the DOT or IATA regulations that are more restrictive than DOT or IATA regulations. The shipper must know what these carrier-specific variances are because they can affect whether a sample can be accepted for shipping, and if, accepted, in what quantity.

6.6.1.2 *Package Volume*—The package should be sufficiently large to hold a reasonable number of sample containers or bottles without exceeding weight limitations.

6.6.1.3 *Ability to Securely Seal the Package*—For some projects, it is necessary to implement a program of sample tamper-proofing which involves the use of security seals and tags on both the sample container or bottle as well as the outer packaging materials.

6.6.1.4 *Leak-proof Package*—When shipping liquid samples or samples packed on wet ice, it is necessary to prevent the release of any liquids in the event of sample container breakage or melting of wet ice. Leakage can be prevented by lining the inside of the outer package with plastic, placing individual sample containers or bottles inside sealed plastic bags, ensuring that outer drain plugs are sealed shut, and placing wet ice inside two bags, at least one of which can be tied closed.

6.6.1.5 *Insulation*—For parameters that require shipment below a specific temperature, it is essential that the outer package be sufficiently insulated to minimize changes in sample temperature during shipment. This is especially true when the shipping period is longer than overnight.

6.6.1.6 *Ease of Handling*—Outer packages may become heavy and awkward once filled, making them difficult to maneuver. It may be preferable to use containers with handles on larger packages, although some carriers assess additional fees if packages have handles.

6.6.1.7 *Materials of Construction*—Package materials should be durable, easy to clean, should not introduce either positive or negative sample bias to the samples, and should be able to hold the weight of the samples being shipped. Materials of construction should be non-absorbent.

6.6.1.8 *Durability and Reusability*—When shipping non-regulated or non-hazardous samples, it is acceptable to reuse shipping packages, such as coolers. Selected packages must be strong enough to retain all structural integrity.

6.6.1.9 *Ease of Cleaning*—The shipping package should be designed so it is easy to access the interior for cleaning.

6.6.2 *Packing Non-Regulated or Non-Hazardous Samples for Shipment*—Once collected, labeled and ready to ship to the laboratory, the shipper must pack the sample containers in a manner to ensure that the physical and chemical integrity of the samples are protected. The shipper must take the following into account when packing these samples for shipment:

6.6.2.1 *Sample Container Breakage*—There are many different materials that can be used to pack sample containers to prevent breakage during shipment. Examples include: bubble wrap, protective sleeves or foam blocks over individual containers, and expanded polystyrene peanuts. Containers should be packed with enough packing material to ensure that containers do not bang against each other or move freely during shipment.

6.6.2.2 *Protection of Sample Labels*—When shipping samples that are liquid or that are being shipped on wet ice, it is important to prevent sample labels from getting wet. Wetting the labels can cause the ink to run or fade, disintegration of the label, or the label to come off the container. It is a common practice to use waterproof labels and indelible ink. Various measures can be taken to prevent or reduce water contact with the labels such as placing a single layer of clear packing tape over the labels.

6.6.2.3 *Preventing Leakage from Outer Packaging*—No liquids should leak from the outer packaging as the result of sample container breakage, condensation on containers or release of melted wet ice. It is recommended that absorbent materials be placed on the bottom of the outer packaging,

between sample containers, and on the top of all containers within the outer packaging once filled. This will help secure sample containers within the outer packaging and will absorb any free liquids. It is also recommended that any outside drain plugs be secured shut. It may also be appropriate to place individual sample containers in a zipper-seal bag within the outer packaging to act as secondary containment for the sample in the event of container breakage. Some containers are coated with a plastic film to prevent leakage of sample in the event the container is broken.

6.6.2.4 Temperature Control—For some samples, it is necessary to ship samples below 4.0°C. As discussed in Practice D 6517, it is recommended that wet ice be used for this purpose. Sufficient ice should be used to cool and maintain samples at the desired temperature until receipt by the laboratory. It is recommended that all wet ice be double-bagged to contain melt water and that at least one bag should be sealed with a knot which will not fail under pressure changes when being shipped by aircraft.

6.6.2.5 Labeling the Outer Packaging—Regulations do not specify any particular requirements for the outer packaging of non-regulated samples. It is necessary to include the complete ship to and return addresses including telephone numbers. Optional, but recommended labeling includes: “Fragile,” “This Side Up,” and “Packed in Wet Ice,” especially when a commercial carrier is shipping samples. It is also recommended by some carriers that a Shipper’s Declaration be placed on the outside of the outer packaging that indicates why samples are being shipped as a non-regulated substances. This can prevent unnecessary opening of the outer packaging by

shipping officials that could compromise any security tags or seals in use. This Shipper’s Declaration must be signed and dated by the shipper. (see Note 5).

6.6.3 Packaging Dangerous or Hazardous Samples for Shipment—Environmental samples that are dangerous or hazardous in nature must be packaged according to the specifications of the selected shipping regulations (Federal, International, state or local) and in compliance with carrier variance requirements. Packaging of environmental samples includes not only the sample bottle or container that is specified by the laboratory’s analytical method, but also includes inner and outer packaging materials. It is the shipper’s responsibility to ensure that the packaging complies with Packing Group requirements, as specified by the shipping regulations, for the hazard associated with the samples being shipped. Only those packaging materials permitted by regulation are to be used and inner and outer packaging materials cannot be reused. Shippers need to be aware that there are restrictions on the number and weight of samples permitted per package and that these limits cannot be exceeded under any circumstance. The shipper must ensure that all packaging materials are assembled correctly and that all required labels and markings are presented on the outer packaging. When shipping materials under the small quantities exception rule, a Dangerous Goods in Small Quantities Label must be used as illustrated in Fig. 1.

NOTE 5—A Shipper’s Declaration is a statement made in writing by the shipper that explains what the contents of the package being shipped are and why the shipment is considered unregulated or non-hazardous. The statement is dated and signed by the shipper and includes a telephone number for the shipper.

FIG. 1 Example of Small Quantities Exception Label

7. Timing of Sample Packaging and Shipment

7.1 *Timing of Sample Packaging*—All environmental samples should be packaged in the field after sample collection and labeling. It may be necessary to cool some water samples to 4.0°C prior to final packaging as discussed in Practice D 6517.

7.2 *Timing of Sample Shipment*—Environmental samples should be shipped in time to assure the arrival of the samples at the laboratory prior to the expiration of the holding time for the analytical parameters of interest. The holding time is specified by the analytical method being used in the laboratory and can vary from hours to months depending upon the parameter. Scheduling of sample shipments should be coordinated with the laboratory as discussed in Guide D 5903.

8. Documentation

8.1 *Chain-of-Custody*—In many circumstances, a Chain-of-Custody form should accompany environmental samples being submitted to a laboratory regardless of the hazard classification of the samples. Chain-of-Custody forms should be completed as described in Guide D 6089. The original Chain-of-Custody form should be included in the outer packaging of samples and contained within a water-proof package to prevent it from becoming wet during sample shipment. A copy of the Chain-of-Custody should be retained by the shipper. Guide D 4840 provides a standardized Chain-of-Custody form.

8.2 *Laboratory-Specific Forms*—In some programs, individual laboratories may have special forms that must accompany samples. These can include project contact information forms and analytical request forms.

8.3 *Shipping Manifests:*

8.3.1 If samples are being shipped as non-regulated or non-hazardous samples, standard shipping labels, forms and air bills can be used on outer packages. Although not required, it is recommended that outer packages be marked with “This Side Up” arrows to help minimize sample breakage due to mishandling of the package and that a Shipper’s Declaration be placed on the exterior of the outer packaging to indicate why samples are being shipped as non-regulated substances. The shipper should retain the shipper’s copy of any manifest and should have a copy of any tracking, delivery confirmation or air bill numbers.

8.3.2 When shipping dangerous or hazardous samples, the shipper must complete the appropriate dangerous goods/hazardous materials manifests. The shipper should retain the shipper’s copy of any manifest and should have a copy of any tracking, delivery confirmation or air bill numbers.

8.4 *Verification of Sample Delivery*—The laboratory should be contacted the day samples are expected to be delivered to verify that samples were received and that samples were in good condition. If samples have not been received, the shipper should use air bill or tracking numbers to determine the location of the samples and anticipated delivery times. In the event that improper packaging of hazardous or dangerous materials causes refusal of sample delivery by the carrier, the shipper will need to contact the carrier to determine what must be done to facilitate sample shipment to the laboratory.

9. Keywords

9.1 carrier; dangerous goods; environmental samples; hazard classifications; packaging; shipper; shipping; transport

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