Designation: D 5111 – 99

Standard Guide for Choosing Locations and Sampling Methods to Monitor Atmospheric Deposition at Non-Urban Locations[1]

This standard is issued under the fixed designation D 5111; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide assists individuals or agencies in identifying suitable locations and choosing appropriate sampling strategies for monitoring atmospheric deposition at non-urban locations. It does not purport to discuss all aspects of designing atmospheric deposition monitoring networks.

1.2 The guide is suitable for use in obtaining estimates of the dominant inorganic constituents and trace metals found in acidic deposition. It addresses both wet and dry deposition and includes cloud water, fog and snow.

1.3 The guide is best used to determine estimates of atmospheric deposition in non-urban areas although many of the sampling methods presented can be applied to urban environments.

2. Referenced Documents

2.1 *ASTM Standards:*

D 1356 Terminology Relating to Atmospheric Sampling and Analysis of Atmospheres[2]

D 1357 Practice for Planning the Sampling of the Ambient Atmospheres[2]

D 3249 Practice for General Ambient Air Analyzer Procedures[2]

D 4841 Practice for Estimation of Holding Time for Water Samples Containing Organic and Inorganic Constituents[3]

D 5012 Guide for Preparation of Materials Used for the Collection and Preservation of Atmospheric Wet Deposition[2]

3. Terminology

3.1 For definitons of terms used in this guide, refer to Terminology D 1356.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *collocated sampling*—the use of more than one sampling device within a monitoring site.

3.2.2 *event sampling*—a special form of intermittent sampling (Terminology D 1356) where the duration of a sampling period is defined as a single, discrete occurrence of precipitation, dew, fog or frost.

3.2.3 *fetch*—a vector within the local area which describes the direction and area of, or within, an air mass that will be sampled by a sampling device.

3.2.4 *filter-pack*—a sampling device comprised of one or more filters in series where each filter is designed to sample an atmospheric chemical species or remove interferences to a subsequent filter. Filters may be of different design; material; or be coated or impregnated to obtain the specificity of chemical species required.

3.2.5 *inferential sampling*—an indirect sampling method that utilizes a mathematical model to quantify an unmeasurable or difficult to measure property of atmospheric deposition.

3.2.6 *local area*—an area of a few square kilometers which describes an area of common vegetation, land-surface form and land use surrounding the monitoring site and defines the local characteristics surrounding the sampling device, see Fig. 1.

3.2.7 *monitoring site*—a radius of a few decameters which immediately surrounds the sampling device, see Fig. 1.

3.2.8 *regional area*—an area between the local area and a threshold that defines where any single local area characteristic can not be distinguished from regional characteristics, see Fig. 1.

3.2.9 *sequential sampling*—withdrawal of a portion of the atmosphere over a period of time with continuous analysis or with separation of the desired material continuously and in a linear form. Such a sample may be obtained with a considerable concentration of the contaminant but it still indicates fluctuations in that property which occur during the period of sampling (Terminology D 1356; see *sample, running*).

3.2.10 *surrogate surface sampling*—a sampling technique that utilizes an artificial surface to estimate dry deposition. Ideally, the artificial surface chosen will approximate the real surface's roughness and wetness properties. In practice this is impossible. Therefore, comparisons of the surrogate surface to the real surface must always be done as a part of the technique.

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[1] This guide is under the jurisdiction of ASTM Committee D22 on Sampling and Analysis of Atmospheres and is the responsibility of D22.06 on Atmospheric Deposition.

Current edition approved September 10, 1999. Published November 1999. Originally published as D 5111 – 90. Last previous edition D 5111 – 95.

[2] *Annual Book of ASTM Standards*, Vol 11.03.

[3] *Annual Book of ASTM Standards*, Vol 11.01.

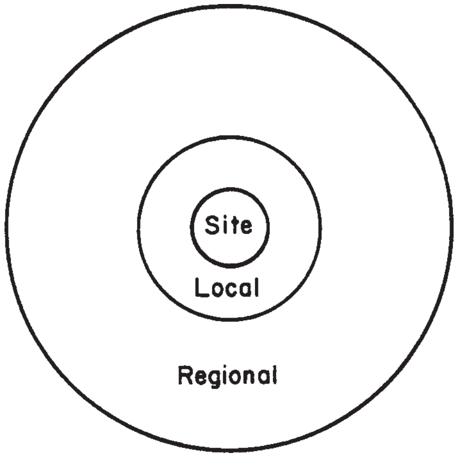

FIG. 1 Diagram of Siting Guidelines

3.2.11 *wet deposition*—the deposition of water from the atmosphere in the form of hail, mist, rain, sleet and snow. Deposits of dew, fog and frost are excluded (Terminology D 1356; see *precipitation, meteorological*).

4. Significance and Use

4.1 The guide consolidates into one document, siting criteria and sampling strategies used routinely in various North American atmospheric deposition monitoring programs.

4.2 The guide leads the user through the steps of site selection, sampling frequency and sampling equipment selection, and presents quality assurance techniques and other considerations necessary to obtain a representative deposition sample for subsequent chemical analysis.

4.3 The guide extends Practice D 1357 to include specific guidelines for sampling atmospheric deposition including acidic deposition.

5. Summary of Guide

5.1 The guide assists the user in establishing siting guidelines and in choosing sampling frequencies and sampling devices for atmospheric deposition monitoring. Special considerations for the monitoring of specific types of atmospheric deposition are discussed.

5.2 A worksheet is provided to assist the user in documenting the final siting criteria and sampling strategy chosen—see Appendix X1.

5.3 The guide references site selection and sampling documents of some of the currently operating deposition monitoring networks in North America (Appendix X2).

6. Sampling Locations

6.1 *General Requirements*:

6.1.1 General requirements for choosing atmospheric deposition sampling locations follow Practice D 1357. This guide should be used in conjunction with that document.

6.1.2 A standardized site description questionnaire should be developed and completed during the site selection process. The questionnaire will describe the chosen location in detail. Examples of these questionnaires can be found in Refs **(1-3).**[4]

6.1.3 Fig. 1 illustrates the concentric organization of location guidelines used in this document. Monitoring site requirements are common to all types of monitoring stations, while regional area requirements invoke a combination of monitoring site, local area and regional area guidelines. Which guidelines within each area category are chosen and whether all area categories are used will depend upon the purpose of the monitoring effort.

6.1.4 Some specific atmospheric deposition sample types require that additional criteria be met. These are identified towards the end of each sampling location section with an appropriate key word; DRY for dry deposition; FOG for fog; etc. Guidelines that contain no key word are common to all types of deposition monitoring within their monitoring site, local area, or regional area grouping.

6.1.5 The user of this guide should use all of the guidelines listed for the deposition type being monitored and all of the guidelines that are not deposition type specific. Exceptions to the use of all of the guidelines should be noted on the worksheet in Appendix X1 of the guide and be accompanied with a brief exclusion statement.

6.2 *Regional Area Guidelines*:

6.2.1 Regional area guidelines should be based upon a consensus interpretation of the concept of regional representativeness by the monitoring project management. Regions may be identified based upon physiography, meteorology, demography or some other more specific goal of the monitoring project. Ground-based concepts of representativeness, such as the ecological classifications of Bailey and others **(4,5)** or areas sensitive to acid deposition, are often more easily defined than meteorological concepts which tend to be highly variable both spatially and temporally. For this reason definitions of regional representativeness based heavily upon meteorological phenomena are best developed *a posteriori* using mathematical and statistical models **(6)**.

6.2.2 When developing regional area guidelines, distance criteria should reflect the thresholds where any characteristics of a local area become indistinguishable from those of other local areas and are instead typical of the area that will be declared a region.

6.2.3 Population centers of greater than 10 000 should be at least 10 km from the sampling device. This distance should be increased dramatically if the sampling device is located downwind of the center in the prevailing wind direction.

6.2.4 All industrial and natural sources of emissions greater than 10 000 tons per annum of each analyte of interest should be at least 10 km from the sampling device. This distance should be increased dramatically if the sampling device is located downwind of the source in the prevailing wind direction.

[4] Boldface numbers in parentheses refer to references at the end of this guide.

6.2.5 Complex terrain should be avoided unless its influence is necessary to meet the specific goal of the monitoring effort.

6.3 *Local Area Guidelines*:

6.3.1 The local area surrounding a monitoring site should describe a small geographic area where land use, topography and meteorology are common and representative of the regional area. No single emission source should dominate the air quality at the site except as it typifies the common emission characteristics of the regional area. Ideal sites will be located in areas where land use practices are not expected to change over the course of the monitoring effort.

6.3.2 Emission source amounts, their frequency and intensity, and meteorological diversity will dominate the actual influence of each guideline on samples collected in any monitoring program. Because of this, local area guidelines are typically the portion of a site selection plan that is not met. A relaxation of the guidelines can be tolerated when the impact of non-compliance on program objectives can be quantified.

6.3.3 Monitoring sites should be located away from population centers. A recommended distance is 1 km per 1000 persons.

6.3.4 Intensive agricultural and waste treatment activities should be more than 500 meters from the sampling device. Dairy operations, crop cultivation, especially in areas where chemical applications are used and solid waste and wastewater treatment facilities are of particular concern.

6.3.5 Transportation related sources of emissions should be no closer than 100 meters from the sampling device. Parking lots, unpaved roadways and high volume vehicular, railroad and airplane traffic are of particular concern. One hundred meters is a minimum acceptable distance cited by some of the existing atmospheric monitoring networks (See X2.3-X2.5). The distance should be increased in proportion to increases in traffic volume and diversity. One kilometer is considered adequate under most conditions.

6.3.6 The open or surface storage of agricultural or industrial products should be kept at least 100 m from the sampling device. Examples of these products would include salt and sand piles, fuels and chemicals.

6.3.7 *Dry*—For methods employing the estimation or use of atmospheric fluxes (see 9.2.3 and 9.2.9), the surface micrometeorology and surface composition should be as uniform as possible within 500 m of the sampling device.

NOTE 1—The success of tower based eddy correlation techniques and many other dry deposition techniques utilizing deposition velocity estimates, are dependent upon the uniformity of the upwind surface roughness and wetness. If the upwind micro-meteorology and surface characteristics enhance the turbulent mixing of the parameter of interest as it approaches the point sampling then the distance requirements for fetch can sometimes be relaxed. If on the other hand deposition rate estimates are expected to be small, the fetch distance requirements may need to be increased (**(7)** see 9.2.3.).

6.3.8 *Dry*—For methods employing the estimation of atmospheric fluxes, see 9.2.3, the sampling device should be located at least 5 km from prominent discontinuities in terrain such as large bodies of water, isolated hills or valleys and cliffs.

6.4 *Monitoring Site Guidelines*:

6.4.1 Monitoring sites should be located on naturally vegetated or grassed, open, level areas. Ground cover should be homogeneous and the area should slope no more than 15 %.

6.4.2 The distance from the sampling device to any object greater than the height of the sampling device should be at least twice the height of the object (2:1). This will ensure that no object or structure will project onto the sampling device with an angle greater than 30° from the horizontal.

6.4.3 With the exception of wind shields, objects with sufficient mass to deflect the wind or otherwise change the aerodynamic properties of the sampling device should be located no closer than 2 m from the sampling device.

NOTE 2—Wind shields are considered to be an integral part of the sampling device in this guide.

6.4.4 Residential structures should be outside of a 30° cone of the prevailing wind direction.

6.4.5 Sampling devices should be oriented towards the annual averaged prevailing wind. In the absence of site specific wind direction information projects should standardize the orientation of the device to one direction.

6.4.6 Seasonal vegetation should be maintained at a level that is at least 1 meter below the orifice of the sampling device to a distance that defines one-half of the monitoring site.

6.4.7 Grazing animals and the cultivation of agricultural crops should not be permitted within the monitoring site.

6.4.8 All activities not directly related to sampling should be discouraged within the monitoring site.

6.4.9 *Snow*—The sampling device should be located in a setting that is sheltered from the wind. Locating the monitoring site within a forest clearing or installing a wind shield around the sampling device improves snow capture **(8)**.

NOTE 3—Wind speeds in excess of 1 m/sec significantly reduce the efficiency of snow sampling devices **(8)**. Light, dry snows are the most difficult to sample. Reducing or eliminating the wind around the sampling device by either shielding the device or locating the device below the vegetation canopy improves snow capture and eliminates re-entrainment of already collected samples.

6.4.10 *Dry*—For methods utilizing towers in the estimation of atmospheric fluxes (9.2.3), the tower heights should be standardized and be at least 5 meters above the surface of interest (for example, forest canopy and agricultural crops). For measurements over bare ground this distance may need to be doubled.

6.4.11 *Dry*—Methods utilizing micro-meteorological measurements in the estimation of atmospheric deposition require stricter slope requirements of 5 % and stricter projection requirements of 5:1, see 6.4.1 and 6.4.2.

7. General Sampling Requirements

7.1 Once the goals of the monitoring effort have been established and site locations have been identified, sampling frequency and sampling equipment decisions can be made. Location decisions should be made in advance of sampling decisions since, in addition to cost, the latter are almost always limited by site availability and accessibility.

7.2 The choice of a sampling method for atmospheric deposition monitoring oftentimes will be a compromise brought about by the availability of a suitable site, the ability of a particular sampling device to selectively measure the deposition type and chemical species of interest, and the differences in cost of implementing some of the available techniques. The selection of sampling intervals and sampling devices may be an iterative exercise especially if a wide variety of chemical species are of interest.

7.3 Users of this guide should recognize that all of the sampling techniques mentioned in this guide are not directly comparable and may not be interchangeable. Comparability, especially in the area of dry deposition, has only recently begun. For projects requiring a wide variety of deposition estimates or short sampling intervals, this often means selecting multiple methods.

7.4 Projects requiring comparability or additivity of estimates derived from more than one method should establish the level of uncertainty in using this approach.

8. Sampling Frequency

8.1 *Continuous Sampling*:

8.1.1 Continuous Sampling in the context of atmospheric deposition monitoring is a combination of both continuous and instantaneous sampling (Terminology D 1356). It is frequently used for the estimation of ambient air concentrations in sampling techniques which compute dry deposition rates. Continuous measurements are typically the most expensive form of measurements to obtain since they most always require sophisticated instrumentation and a high level of expertise to minimize and troubleshoot periods of non-sampling.

8.1.2 Continuous sampling should only be considered when instantaneously sampled deposition data are necessary, as in dose response types of effects studies, when averaged information is necessary to statistically reduce error estimates, or, as in the calculation of dry deposition rates, instantaneous sampling results must be paired with instantaneous meteorological measurements.

8.1.3 General recommendations for continuous ambient air analyzers are given in Practice D 3249.

8.2 *Cumulative Sampling*:

8.2.1 Cumulative samples represent a temporal composite or integration of the parameter being monitored. The length of time a sample accumulates in the sampling device can be adjusted to match the temporal resolution required in the monitoring program. Intervals of days through months are typical for wet deposition and hours through weeks are typical for dry deposition. Cumulative sampling is the most widely used technique in both wet and dry deposition.

8.2.2 When using cumulative sampling, attention must be paid to the possibility of sample degradation that can occur during the accumulating time period. Short accumulation times are recommended, especially when samples are not preserved. Both loss and transformation of chemical species have been observed in cumulative samples **(9,10)**.

8.2.3 Cumulative sampling can be used to reduce the number of samples collected and analyzed along with their associated costs, and to increase the sensitivity of a method by averaging over time. Filter packs, denuders and impingers all use the principle of cumulative sampling.

8.3 *Event Sampling*:

8.3.1 Event sampling is a special form of intermittent sampling used to collect liquid deposition from discrete occurrences of precipitation, dew, frost, and fog.

8.3.2 Event sampling is used for studying atmospheric processes and for determining noncumulative effects of atmospheric deposition on agricultural and natural ecosystems. Event sampling is especially useful when monitoring objectives are associated with episodic phenomena such as storm types, direction or intensity, or when the tracking of a parameter through time and space is required.

8.3.3 Event sampling is less susceptible to the sample integrity problems associated with cumulative sampling **(9,10)**. This is especially noticeable when events are of short duration (for example, less than days).

8.3.4 Event sampling is not an effective monitoring frequency when the predominant sample collected contains too small an amount of analyte mass for analysis or consistently produces analyte concentrations below the method detection limit. The cost of standby time (time waiting for events to occur) should also be considered when selecting event sampling frequencies.

8.4 *Sequential Sampling*:

8.4.1 Sequential sampling is used to characterize within event variability. Sequential sampling strategies typically break events into consecutive, equal-volume or equal-time subsamples of the event. Like event sampling, sequential sampling is limited to liquid deposition types and is used to study atmospheric processes.

8.4.2 Sequential sampling should only be used when project goals emphasize within event variability as more or equally as important as between event variability. It is seldom considered for long-term monitoring.

8.4.3 All of the cautions of event sampling—see 8.3.3 and 8.3.4—also apply to sequential sampling.

9. Sampling Devices and Techniques

9.1 *Wet Deposition*:

9.1.1 *General Characteristics*—Wet deposition sampling devices typically consist of a precipitation detector or sensor and a mechanically operated lid which covers a sample container or inlet. The sensor detects the presence of water and activates the mechanical lid which exposes the sample container or inlet to precipitation. At the cessation of precipitation the lid returns to a position which protects the sample container from dry deposition. Any sampling system that has the ability to capture wet-only precipitation and protect the captured sample from dry deposition can be used.

9.1.2 A wet deposition collector is designed to capture a representative sample of precipitation for subsequent chemical analysis and prevent this captured precipitation from mixing with other forms of deposition. Because the emphasis of the design is towards representative chemistry and not necessarily on the quantification of precipitation amount, the collector should not be relyed upon for estimates of precipitation volume (see 9.1.4).

9.1.3 *Precipitation Sensors*—Most precipitation sensors work on a resistance principle, interrupting or establishing an electrical current when their surface becomes wet. Heating devices in the sensor attempt to evaporate the accumulated water from the sensor surface, returning the sensor to a dry status. The resistance setting, surface area and heating rate of the sensor determines the sensitivity of the sensor to the wetness created during a precipitation, fog, dew or frost event. A sensor's selectiveness towards these deposition types can be altered by altering the resistance, heating rate, temperature and surface area of the sensor, and by controlling the response time between the electrical detection of wetness and the activation of the collector's mechanical system. Sensor resistance, heating rates and temperature, surface area and activation delay capability should be chosen to emphasize the goals of the monitoring project.

NOTE 4—It should be recognized, that all wet deposition collectors capture small amounts of dew, frost and fog and that the sensor plays a critical role in determining the sensitivity of the collector to these forms of deposition. The sensor design should restrict the collection of dew, frost and fog and improve the likelihood of collecting a wet-deposition-only sample.

9.1.4 *Collector Sampling Efficiency*— Because a wet deposition collector relies on the movement of a mechanical lid to expose its sampling container or activate its sampling system, it does not always open or close in perfect sequence with the initiation or cessation of precipitation. Differences in the collector's aerodynamic design and its' sensor's characteristics will largely determine the suitability of the collector for certain geographic and climatic conditions. Snow accompanied by wind is especially difficult to sample. The performance of the collector under the geographic and seasonal climatic conditions in which it will operate should be established so that sampling biases towards specific deposition types or conditions are minimized and so that the sampling efficiency of the device is characterized. Collector sampling efficiency is best determined by comparing the volume in the wet deposition collector to the volume of a collocated national meteorological service or World Meteorological Organization (WMO) rain gage.

9.1.5 *Sample Integrity Considerations*— The construction and workings of the mechanical lid which covers the wet deposition sample is a critical component of the wet deposition collector. The lid should be designed in such a manner as to seal the deposition sample during periods of dry deposition in order to minimize the chance for sample degradation due to evaporation, diffusion, thermal decomposition and wind-borne contamination. No device will perform ideally, but careful attention to the workings and materials of construction of the lid will improve the representativeness of the wet deposition sample collected.

9.2 *Dry Deposition*:

9.2.1 *General Principles*—Sampling techniques used for the measurement of dry deposition are as varied as the substances they are designed to quantify. Each requires a different level and area of expertise and has only limited flexibility for sampling a variety of chemical species and deposition types. Most techniques represent innovative approaches to resolving the critical needs of dry deposition sampling in specific locations (forests vs grasslands) or for specific receptors (such as a plant species or blocks of marble).

9.2.2 Many of the dry deposition estimation techniques involve the measurement of one or more chemical or meteorological parameter and the application of some type of mathematical model to quantify dry deposition. The model may be a simple difference equation or a complex sequence of equations designed to simulate natural science theories under different conditions of meteorology, and other site specific physiographic features.

NOTE 5—The use of a model to estimate dry deposition requires that meteorological and chemical measurement techniques be available for the time and spatial scales used by the model and for the complexity of the terrain. It is further required that the combination of model and measurements be specific to the surface that is receiving the deposition. Models and measurements for most chemical species under various terrain and meteorological conditions are still rather limited. For a more complete compilation of current applications the reader is referred to Ref (**10**).

9.2.3 *Inferential Methods*—These methods require micrometeorological measurements, air concentration measurements, a suitable mathematical model **(11,12)** that allows the user to infer the dry deposition velocity (V_d) for the chemical species being monitored from the reported micrometeorological data and site surface observations of specific type and condition. The methods result in deposition rate estimates which can be used to establish deposition loading. The methods are often limited by the lack of chemical analysis techniques or the costs of utilizing continuous gas analyzers. The current models tend to be very specific to terrain, surface composition and surface condition. When choosing these techniques users should be certain that 1) there is an available model for the chemical species and time scale of interest 2) there is a chemical measurement technique for the chemical state and sampling frequency required 3) sampling sites meet the surface composition and condition requirements of the model and 4) the assumptions implicit to the chosen model are appropriate for the proposed project.

9.2.4 For studies requiring chemical measurements spanning days or weeks, continuous meteorological measurements are typically integrated as appropriate to the model. Impingers, denuders and filter packs are the chemical sampling methods of choice **(13)** . Changes in micro-meteorological conditions and in surface characteristics (wetness, stage of growth, etc) during the sampling period however, often results in abnormal or unrealistic integrations of meteorological or surface parameters causing the models to run outside of their designed limits.

9.2.5 When the cost and availability of continuous gas analyzers are feasible, usually for short duration projects at a single site, models can be chosen to make maximum use of meteorological and surface driven parameters. Dry deposition estimates utilizing inferential techniques are best suited to studies where the monitoring site has flat, homogeneous terrain, and where the meteorology is relatively uniform throughout a day.

9.2.6 *Methods Based Upon Surface Analysis*—Surface analysis methods estimate the deposition loading to surfaces during non-precipitation periods either by direct analysis of the surface that is receiving the deposition [foliar extraction, surrogate surfaces **(7,14)**] or by using techniques that compute dry deposition by difference [throughfall/stemflow estimation, runoff/catchment mass balancing, snow sampling **(7,14)**]. The methods are usually confined to specific ecological regions (forests, watersheds) and seasons (with foliage, with snow) where representative surfaces are available and conventional surface sampling techniques can be applied.

NOTE 6—Siting requirements given in 6.4.1, 6.4.3 and 6.4.5 are meaningless and therefore unnecessary for surface analysis methods using natural, living surfaces (for example, foliar extraction, throughfall, etc) as the deposition collector. Requirement 6.4.2 should also be examined for suitability.

9.2.7 Surrogate surface techniques are effective in quantifying chemical species where gravitational settling of large particles dominate the dry deposition process. Therefore, users of surrogate surfaces should evaluate the representativeness of the surrogate under various climatic conditions which might alter the surrogate's aerodynamics or other surface conditions. When used in lieu of vegetation, surrogates should also be evaluated as to how they perform in contrast to the vegetation's normal physiological processes (that is, leaf movement, changes in stomatal status, etc).

9.2.8 Users of techniques which derive dry deposition estimates by difference, need to ensure that integration times, usually storms through seasons, are long enough to produce calculated differences that are in excess of the sum of the errors associated with each measured variable used in the difference calculation. Techniques using differences are most effective when the chemical composition of all other components of the equation except dry deposition can be easily characterized and are well understood.

9.2.9 *Atmospheric Flux Methods*—Current methods [eddy correlation, eddy accumulation, vertical gradient, aerometric mass balance, etc **(7,14)**] like the inferential methods, also require micro-meteorological measurements and air concentration measurements. These methods however, compute deposition velocities (V_d) as a part of their model rather than assume them.

9.2.10 Because the deposition velocities are being computed within the technique, instrumentation requirements tend to be more rigorous. The lack of inexpensive accurate and fast response sensors both for meteorological and chemical parameters, and the increased need for more detailed and timely surface characterization information (roughness and wetness) tend to limit the techniques to specific research situations.

9.3 *Fog/Cloud Water Collectors*:

9.3.1 Sampling equipment designed to collect fog and cloud water work on the principles of interception and/or impaction **(15)**. Small diameter (5-410 µm) filaments are used to passively or dynamically intercept cloud or fog water and direct it towards a storage container. Mechanical rotation or moderate volume air movement (nominally 1.5 m^3/min utilizing positive or negative pressure) is often used to increase the collection efficiency of the device. Sampling intervals may range from hours through events.

9.3.2 Like wet deposition collectors, fog and cloud water collectors are designed to collect a representative sample for subsequent chemical analysis. They may not be a reliable way of quantifying fog or cloud water volumes.

9.4 *Bulk Sampling*:

9.4.1 Bulk sampling is the combined collection of both wet and dry deposition into a single container. Bulk sampling describes a wide variety of collection designs from simple open containers to the sub-surface sampling of snow and ice. Each attempts to collect total deposition over some unit of time. Typically collection is passive employing collectors constructed from a bucket or funnel. These containers collect all forms of deposition that come in contact with their exposed surfaces.

9.4.2 Bulk sampling has the advantage of simplicity, being a passive device that requires no power. In many instances however, it has been shown to be susceptible to chemical contamination from other than atmospheric sources (bird droppings, twigs, etc) and to evaporation losses. In some instances, bulk collectors may not preserve the speciation of collected deposition, especially if the sampling device allows free interaction between both the wet and dry components of the deposition process and the atmosphere.

9.4.3 With the possible exceptions of snow sampling and in cases where dry deposition is accomplished almost exclusively by gravitational settling of coarse particles, bulk deposition collectors are not recommended. If used, it is recommended that sampling be initiated just prior to a precipitation event and concluded within 12 hours after the cessation of precipitation.

9.4.4 Bulk sampling has been used effectively to estimate the deposition of snow **(16)**. Differences between samples taken from recent snow events versus those of previous snow events (snow boards) have also been used to apportion wet and dry components of deposition. Snow and ice cores have also been shown to be effective methods of obtaining bulk samples when sampling times are considerate of the changes in chemical composition that take place during freeze/thaw cycles **(17)**.

10. Quality Control/Quality Assurance

10.1 *Sample Containers*:

10.1.1 Sampling containers, both those used for sample collection and sample transportation should be chosen to minimize sample contamination, chemical species transformation, microbial activity and liquid evaporation. When appropriate rigid containers can not be found for the sampling device chosen, bag liners may be utilized. Bags have the advantages of being disposable and have a more uniform surface chemical composition than can be obtained by recycling glass or plastic ware. Bag manufacturing lots however, need to be monitored to ensure chemical uniformity over the life of the project. All containers used in the routine sampling of wet deposition should be prepared in accordance with Guide D 5012.

10.1.2 Many of the sample containers used in dry deposition techniques are an integral part of or comprise the sampling device. For this reason dry deposition sample containers and filters should be prepared according to the specific demands of the technique.

10.1.3 Filter media used in many dry deposition techniques should be standardized and bought in large lots if possible. Analysis of each lot should be conducted to document any changes in the amount or frequency of false positive analyte loading.

10.1.4 Contamination and analysis errors may be further minimized by choosing a single container for both collection and transport of the deposition sample. Large containers however may be expensive to transport.

10.1.5 Color and texture as well as composition (glass, plastic, etc) should be considered when choosing sample containers and filter media. The choices should be standardized throughout the life of the project. Dark colors promote the absorption of heat when exposed to sunlight. This might be beneficial in some situations to minimize freezing or encourage thawing. Surface roughness and porosity, especially in dry deposition techniques, can alter the yield of sampled material or complicate chemical extraction techniques.

10.1.6 Bag liners and other types of single-use containers, including coated filters, impingers and denuders used in dry deposition techniques should be monitored for changes in their chemical contribution to the analyte measurements.

10.2 *Sample Preservation*:

10.2.1 Sample preservation techniques may be incorporated into sampling device designs (that is, refrigeration) or implemented as a part of the standard sampling protocols. Multiple preservation techniques may need to be applied to a collected sample. The use of these techniques may necessitate the aliquoting of the sample at or near the time of collection and prior to sample transport. Aliquoting may also be necessary to meet the holding time requirements of some analytes (Practice D 4841).

10.2.2 Common techniques employed include filtration, refrigeration, acidification and the addition of biocides. The different techniques are discussed in Guide D 5012.

10.3 *Site Audits*:

10.3.1 Site description questionnaires, see 6.1.2, should periodically be reviewed to ensure their continued compliance with established site criteria. Reviews should include a reevaluation of all emission sources and any local changes in land use or condition.

10.3.2 Routine collector maintenance, along with the use of standard reference materials and calibration checks, should be incorporated into the project's quality assurance program. A wet deposition collector's sensors, lid and drive mechanism should be checked at the end of each sampling interval to ensure proper operation. Wet deposition and bulk collection sample volumes should constantly be compared to national meteorological service or WMO approved rain gages to maintain a record of the collector's sampling efficiency.

10.3.3 Many dry deposition methods require that air handling equipment and other meteorological equipment calibration be maintained. Error analysis of the measurement system should be monitored to ensure that results are significantly above noise levels. This is especially true for methods deriving estimates by difference.

10.4 *System Performance Audits*:

10.4.1 A review of the frequency and magnitude of false-positive measurements of deposition should be conducted periodically to quantify, in parts and as a whole, the contribution of analyte that is associated with violations of sample integrity (collector lid seals, sample container contamination, etc), analytical bias (due to the collector or chemical analysis methodology) and data transformation and summarization (signal integration biases, detection limit values becoming real values, the fate of low volume or analyte events). Both field and laboratory contributions to false-positive measurement should be examined.

10.4.2 Collocated sampling equipment within the monitoring project as well as between monitoring programs should be implemented to allow system wide estimates of measurement precision and bias. The co-location protocol should duplicate the entire monitoring protocol through data management. Duplicate sampling is also useful for overall error estimation.

10.4.3 Sampling completeness statistics should be computed for annual and seasonal comparisons of representativeness **(18)**. The completeness figures provide the percent of deposition collected as compared to a referenced amount, define the percent of samples that are ultimately valid after using the chosen protocols and establish the percentage of samples containing various levels or degrees of severity of caveats in the declared data set.

11. Keywords

11.1 atmospheric deposition; dry deposition monitoring; sampling methods; siting guidelines; wet deposition

APPENDIXES

(Nonmandatory Information)

X1. WORKSHEET FOR CHOOSING SAMPLING LOCATIONS AND SAMPLING METHODS FOR MONITORING ATMOSPHERIC DEPOSITION AT NON-URBAN LOCATIONS

Project Title:	____________________
Project Objectives:	____________________
	Circle One on Each Line
Type and Method of Sampling:	*wet-only* *rain* *snow* *dry* *snow-only* *bulk* *fog* *cloud water* *fog/cloud water* *dew/frost* *inferential* ________ *surface analysis* *flux*
Sampling Frequency:	*continuous* *cumulative* *event* *sequential*
Comments	____________________
Monitoring Site and Area Diameters	*Monitoring Site* ______ *Local Area* ______ *Regional Area* ______

ASTM Siting Modifications: *Section*	*Changes*	*Stricter ?*
______	______	______
______	______	______
______	______	______
______	______	______
______	______	______
______	______	______
______	______	______
______	______	______

Equipment Needed: *Analyte*	*Type of Sampling Device*	*Operator Time/WK*
______	______	______
______	______	______
______	______	______
______	______	______
______	______	______
______	______	______
______	______	______
______	______	______
______	______	______
Totals	*Equipment Costs* ______	*Operator Time* ______

X2. REFERENCES FOR LOCATION CRITERIA AND SAMPLING METHODS USED IN EXISTING ACIDIC DEPOSITION MONITORING NETWORKS

X2.1 Acid Precipitation In Ontario Study-Daily Network (APIOS-D)

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Canadian Air and Precipitation Monitoring Network. *Technical Manual: Canadian Air and Precipitation Monitoring Network*, TM 09-01-01. Atmospheric Environment Service, Environment Canada, Downsview, Ontario. January 1984.

X2.3 Electric Power Research Institute's Utility Acid Precipitation Study (EPRI/UAPSP)

Topol, L. E. *Utility Acid Precipitation Study Program: Network Description and Measurements for 1981 thru 1987*, UAPSP 117, Utility Acid Precipitation Study Program. Washington, DC, October 1989.

X2.4 National Atmospheric Deposition Program/National Trends Network (NADP/NTN)

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Bigelow, D. S. and Dossett, S. R. *NADP Instruction Manual: Site Operations*. National Atmospheric Deposition Program, Natural Resource Ecology Laboratory, Colorado State University, Ft. Collins, CO. April 1988.

X2.5 National Dry Deposition Network (NDDN)

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