Sampling errors are generally believed to dominate the errors of analytical measurement during the entire environmental data acquisition process. Unfortunately, environmental sampling errors are hardly quantified and documented even though analytical errors are frequently yet improperly reported to the third decimal point in environmental analysis. There is a significant discrepancy in directly applying traditional sampling theories (such as those developed for the binary particle systems) to trace levels of contaminants in complex environmental matrices with various spatial and temporal heterogeneities. The purpose of this critical review is to address several key issues in the development of an optimal sampling strategy with a primary goal of sample representativeness while minimizing the total number of samples and sampling frequencies, hence the cost for sampling and analysis. Several biased and statistically based sampling approaches commonly employed in environmental sampling (e.g. judgmental sampling and haphazard sampling vs. statistically based approaches such as simple random, systematic random, and stratified random sampling) are examined with respect to their pros and cons for the acquisition of scientifically reliable and legally defensible data. The effects of sample size, sample frequency and the use of compositing are addressed to illustrate the strategies for a cost reduction as well as an improved representativeness of sampling from spati
ally and temporally varied environmental systems. The discussions are accompanied with some recent advances and examples in the formulation of sampling strategies for the chemical or biological analysis of air, surface water, drinking water, groundwater, soil, and hazardous waste sites.