ENVIRONMENTAL MONITORING

Environmental monitoring describes the processes and activities that need to take place to characterize and monitor the quality of the environment. Environmental monitoring is used in the preparation of environmental impact assessments, as well as in many circumstances in which human activities carry a risk of harmful effects on the natural environment. All monitoring strategies and programs have reasons and justifications which are often designed to establish the current status of an environment or to establish trends in environmental parameters.

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Air quality monitoring

Air pollutants are atmospheric substances—both naturally occurring and anthropogenic—which may potentially have a negative impact on the environment and organism health. With the evolution of new chemicals and industrial processes has come the introduction or elevation of pollutants in the atmosphere, as well as environmental research and regulations, increasing the demand for air quality monitoring.

Air quality monitoring is challenging to enact as it requires the effective integration of multiple environmental data sources, which often originate from different environmental networks and institutions. These challenges require specialized observation equipment and tools to establish air pollutant concentrations, including sensor networks, geographic information system (GIS) models, and the Sensor Observation Service (SOS), a web service for querying real-time sensor data.[2] Air dispersion models that combine topographic, emissions, and meteorological data to predict air pollutant concentrations are often helpful in interpreting air monitoring data. Additionally, consideration of anemometer data in the area between sources and the monitor often provides insights on the source of the air contaminants recorded by an air pollution monitor.

Air quality monitors are operated by citizens, regulatory agencies, and researchers to investigate air quality and the effects of air pollution. Interpretation of ambient air monitoring data often involves a consideration of the spatial and temporal representativeness of the data gathered, and the health effects associated with exposure to the monitored levels. If the interpretation reveals concentrations of multiple chemical compounds, a unique "chemical fingerprint" of a particular air pollution source may emerge from analysis of the data.

Air sampling

Passive or "diffusive" air sampling depends on meteorological conditions such as wind to diffuse air pollutants to a sorbent medium. Passive samplers have the advantage of typically being small, quiet, and easy to deploy, and they are particularly useful in air quality studies that determine key areas for future continuous monitoring.

Air pollution can also be assessed by biomonitoring with organisms that bioaccumulate air pollutants, such as lichens, mosses, fungi, and other biomass. One of the benefits of this type of sampling is how quantitative information can be obtained via measurements of accumulated compounds, representative of the environment from which they came. However, careful considerations must be made in choosing the particular organism, how it's dispersed, and relevance to the pollutant.

Other sampling methods include the use of a denuder, needle trap devices, and microextraction techniques.

Soil monitoring

Soil monitoring involves the collection and/or analysis of soil and its associated quality, constituents, and physical status to determine or guarantee its fitness for use. Soil faces many threats, including compaction, contamination, organic material loss, biodiversity loss, slope stability issues, erosion, salinization, and acidification. Soil monitoring helps characterize these threats and other potential risks to the soil, surrounding environments, animal health, and human health.

Assessing these threats and other risks to soil can be challenging due to a variety of factors, including soil's heterogeneity and complexity, scarcity of toxicity data, lack of understanding of a contaminant's fate, and variability in levels of soil screening. This requires a risk assessment approach and analysis techniques that prioritize environmental protection, risk reduction, and, if necessary, remediation methods.[18] Soil monitoring plays a significant role in that risk assessment, not only aiding in the identification of at-risk and affected areas but also in the establishment of base background values of soil.

Soil monitoring has historically focused on more classical conditions and contaminants, including toxic elements (e.g., mercury, lead, and arsenic) and persistent organic pollutants (POPs). Historically, testing for these and other aspects of soil, however, has had its own set of challenges, as sampling in most cases is of a destructive in nature, requiring multiple samples over time. Additionally, procedural and analytical errors may be introduced due to variability among references and methods, particularly over time.[19] However, as analytical techniques evolve and new knowledge about ecological processes and contaminant effects disseminate, the focus of monitoring will likely broaden over time and the quality of monitoring will continue to improve.

Soil sampling

The two primary types of soil sampling are grab sampling and composite sampling. Grab sampling involves the collection of an individual sample at a specific time and place, while composite sampling involves the collection of a homogenized mixture of multiple individual samples at either a specific place over different times or multiple locations at a specific time.[20] Soil sampling may occur both at shallow ground levels or deep in the ground, with collection methods varying by level collected from. Scoops, augers, core barrel, and solid-tube samplers, and other tools are used at shallow ground levels, whereas split-tube, solid-tube, or hydraulic methods may be used in deep ground.

Monitoring programs

1. **Soil contamination monitoring**

Soil contamination monitoring helps researchers identify patterns and trends in contaminant deposition, movement, and effect. Human-based pressures such as tourism, industrial activity, urban sprawl, construction work, and inadequate agriculture/forestry practices can contribute to and make worse soil contamination and lead to the soil becoming unfit for its intended use. Both inorganic and organic pollutants may make their way to the soil, having a wide variety of detrimental effects. Soil contamination monitoring is therefore important to identify risk areas, set baselines, and identify contaminated zones for remediation. Monitoring and analytical equipment will ideally will have high response times, high levels of resolution and automation, and a certain degree of self-sufficiency.[Chemical techniques may be used to measure toxic elements and POPs using chromatography and spectrometry, geophysical techniques may assess physical properties of large terrains, and biological techniques may use specific organisms to gauge not only contaminant level but also byproducts of contaminant biodegradation. These techniques and others are increasingly becoming more efficient, and laboratory instrumentation is becoming more precise, resulting in more meaningful monitoring outcomes.

2. **Soil erosion monitoring**

Soil erosion monitoring helps researchers identify patterns and trends in soil and sediment movement. Monitoring programs have varied over the years, from long-term academic research on university plots to reconnaissance-based surveys of biogeoclimatic areas. In most methods, however, the general focus is on identifying and measuring all the dominant erosion processes in a given area.[25] Additionally, soil erosion monitoring may attempt to quantify the effects of erosion on crop productivity, though challenging "because of the many complexities in the relationship between soils and plants and their management under a variable climate."

3. **Soil salinity monitoring**

Soil salinity monitoring helps researchers identify patterns and trends in soil salt content. Both the natural process of seawater intrusion and the human-induced processes of inappropriate soil and water management can lead to salinity problems in soil, with up to one billion hectares of land affected globally (as of 2013). Salinity monitoring at the local level may look closely at the root zone to gauge salinity impact and develop management options, whereas at the regional and national level salinity monitoring may help with identifying areas at-risk and aiding policymakers in tackling the issue before it spreads. The monitoring process itself may be performed using technologies such as remote sensing and geographic information systems (GIS) to identify salinity via greenness, brightness, and whiteness at the surface level. Direct analysis of soil up close, including the use of electromagnetic induction techniques, may also be used to monitor soil salinity.

Water quality monitoring

Electrofishing survey methods use a mild electric shock to temporarily stun fish for capture, identification and counting. The fish are then returned to the water unharmed.

Design of environmental monitoring programmes

Water quality monitoring is of little use without a clear and unambiguous definition of the reasons for the monitoring and the objectives that it will satisfy. Almost all monitoring (except perhaps remote sensing) is in some part invasive of the environment under study and extensive and poorly planned monitoring carries a risk of damage to the environment. This may be a critical consideration in wilderness areas or when monitoring very rare organisms or those that are averse to human presence. Some monitoring techniques, such as gill netting fish to estimate populations, can be very damaging, at least to the local population and can also degrade public trust in scientists carrying out the monitoring.

Almost all mainstream environmentalism monitoring projects form part of an overall monitoring strategy or research field, and these field and strategies are themselves derived from the high levels objectives or aspirations of an organisation. Unless individual monitoring projects fit into a wider strategic framework, the results are unlikely to be published and the environmental understanding produced by the monitoring will be lost.

Parameters

- **Chemical**

Analyzing water samples for pesticides

The range of chemical parameters that have the potential to affect any ecosystem is very large and in all monitoring programmes it is necessary to target a suite of parameters based on local knowledge and past practice for an initial review. The list can be expanded or reduced based on developing knowledge and the outcome of the initial surveys.

Freshwater environments have been extensively studied for many years and there is a robust understanding of the interactions between chemistry and the environment across much of the world. However, as new materials are developed and new pressures come to bear, revisions to monitoring programmes will be required. In the last 20 years acid rain, synthetic hormone analogues, halogenated hydrocarbons, greenhouse gases and many others have required changes to monitoring strategies.

- **Biological**

In ecological monitoring, the monitoring strategy and effort is directed at the plants and animals in the environment under review and is specific to each individual study.

However, in more generalised environmental monitoring, many animals act as robust indicators of the quality of the environment that they are experiencing or have experienced in the recent past. One of the most familiar examples is the monitoring of numbers of Salmonid fish such as brown trout or Atlantic salmon in river systems and lakes to detect slow trends in adverse environmental effects. The steep decline in salmonid fish populations was one of the early indications of the problem that later became known as acid rain.

- **Radiological**

Radiation monitoring involves the measurement of radiation dose or radionuclide contamination for reasons related to the assessment or control of exposure to ionizing radiation or radioactive substances, and the interpretation of the results. The ‘measurement’ of dose often means the measurement of a dose equivalent quantity as a proxy (i.e. substitute) for a dose quantity that cannot be measured directly. Also, sampling may be involved as a preliminary step to measurement of the content of radionuclides in environmental media.

Radiation monitoring is often carried out using networks of fixed and deployable sensors such as the US Environmental Protection Agency's Radnet and the SPEEDI network in Japan. Airborne surveys are also made by organizations like the Nuclear Emergency Support Team.

- **Microbiological**

Bacteria and viruses are the most commonly monitored groups of microbiological organisms and even these are only of great relevance where water in the aquatic environment is subsequently used as drinking water or where water contact recreation such as swimming or canoeing is practised.

Although pathogens are the primary focus of attention, the principal monitoring effort is almost always directed at much more common indicator species such as *Escherichia coli*, supplemented by overall coliform bacteria counts. The rationale behind this monitoring strategy is that most human pathogens originate from other humans via the sewage stream. Many sewage treatment plants have no sterilisation final stage and therefore discharge an effluent which, although having a clean appearance, still contains many millions of bacteria per litre, the majority of which are relatively harmless coliform bacteria. Counting the number of harmless (or less harmful) sewage bacteria allows a judgement to be made about the probability of significant numbers of pathogenic bacteria or viruses being present. Where *E. coli* or coliform levels exceed pre-set trigger values, more intensive monitoring including specific monitoring for pathogenic species is then initiated.

- **Populations**

Monitoring strategies can produce misleading answers when relaying on counts of species or presence or absence of particular organisms if there is no regard to population size. Understanding the populations dynamics of an organism being monitored is critical.

As an example, if presence or absence of a particular organism within a 10 km square is the measure adopted by a monitoring strategy, then a reduction of population from 10,000 per square to 10 per square will go unnoticed despite the very significant impact experienced by the organism.