# Environmental Impact Measurements: Tool and Techniques

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## Contents

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## Abstract

The ecosystem provides various services such as regulation, support, provisions and culture to living beings on the earth. The productivity of a system is greatly affected by the health of the different components and the level of contamination in it. Increasing industrialization and reduced sources of natural resources for safe use by the growing population leads to poor productivity of ecosystems. Environmental impact assessment is a current need for the sustainable survival of human being on earth. The increasing industrialization and population, as well as mismanagement of natural resources, are creating environmental threats. Nowadays people are more worried about natural calamities and the substantial reduction of environmental quality worldwide. Many techniques are available to assess and determine environmental factor intensity and quality at any given time. Therefore, the use of modern technologies in this field can be a viable option to warn of natural calamities and to save or effectively manage human life and natural resources. Most developing countries today need to execute environmental policy and effective guidelines, and provide the infrastructure, to accurately assess environmental effects on natural resources and the ecosystem's different biogeochemical cycles. Spreading awareness among people through governments and nongovernmental organizations also has a valuable place in combating the incidence of natural calamities and the deterioration of environmental health.

## Introduction

The environment is a protective cover for living organisms on the earth. In common terms, "environment" refers that all biotic and abiotic things and their interactions with biotic organisms, nonliving things, weather and climatic conditions, and natural resources. The term has been defined differently by different field of studies and their available knowledge and priorities. One field of specialization may be concerned with particular parameters of an environment, whereas another field of science may emphasize others. Natural management researchers focus more on conservation and rational utilization of soil, water, and other available resources on earth, with less emphasis on environmental aspects. Economists, on the other hand, may be more concerned with per-unit investment of credit and less focused on environmental health.

Such ambiguity in environmental perspectives promotes environmental contamination and adversely affects economic and demographic activities within the global market. The International Association for Impact Assessment defines the environmental impact assessment (EIA) as "the process of identifying, predicting, evaluating and mitigating the biophysical, social, and other relevant effects of development proposals prior to major decisions being taken and commitments made" [1]. Some procedures need specialized skills and tools assess real problems in ecosystems [2, 3]. The initial cost of instrumentation is high, and smaller organizations may not be able to afford it [4]. Inventories of precious natural resources and their utilization for the welfare of people are clearly depicted in national and international policies formulated by the governments of some countries. On the basis of environmental impact, these policies may be enacted at regional, national, or international levels; the scale of impact assessments also change with the type of problem and its adverse effect on an ecosystem's activities. Modern technology and advanced scientific research may lead to identification of the exact impact of environmental calamities [5, 6] contaminants to health, and the availability of natural resources on a global scale [7].

The changing scenario of climate change greatly affects environmental quality and its functions across the globe. Climate change is unequivocal, and its impact on the Indian agricultural production system can already be felt. The climatic changes have mediated soil-forming processes [8, 9], crop productivity [10], and microbial diversity in soil [11]. Increases in atmospheric temperature enhances the respiration rate in plant; and reduces biomass production [12]. This situation is a bit different in low-temperature zones, where increasing temperatures enhance biomass production and crop yields. Increased concentrations of greenhouse gases (GHGs) in the atmosphere enhance the global temperature and affect the depreciation rate of various processes on earth [13]. Numerous agricultural management strategies play a crucial role in minimizing the emission of GHGs into the atmosphere, and, accordingly, impact assessments need to scale up local situations and resource availability [14, 15]. The primary GHGs in the earth's atmosphere are water vapor, $CO_2$, $CH_4$, $N_2O$, and ozone gas. Agriculture is a potential source of ($CO_2$, $N_2O$ and $CH_4$) and sink for ($CO_2$) GHGs. Adopting agricultural process focused on conservation and dominant cropping systems; adjusting agricultural inputs and land use management practices; and enhancing resource use efficiency, waste recycling, and solid waste management are some of the key options available for developing climate resilience [13]. Management of agricultural land, land use changes, and forest cover profoundly influences the concentration of GHGs in the atmosphere. Regularly and more precisely monitoring changes in climatic events is needed to better use and avoid massive losses of human life as well as economic losses in a country.

Assessment of environmental qualities or parameters is necessary to execute different developmental activities within a region. Public services infrastructure, healthy crop production, industrial growth and development, and wildlife survival must be established [4]. Agricultural crop fields are already categorized per impact analyses of crop productivity with respect to climatic and soil conditions. Soil surveys and land use planning classify agricultural land on the basis of soil characteristics and constraints for agricultural crop production [16]. In a similar way, forested areas are also studied using environmental impact analyses. Environmental impact analysis is a valuable tool when the climatic conditions within a region abruptly change, as is happening now in some areas . It is also important to take appropriate remediation measures to combat adverse conditions and minimize loss to the ecosystems. This assessment also very complex, with relations between soil types, vegetation, climatic conditions, pollutants and local management options [17, 18]. Selecting the right approach with a high degree of sensitivity to determine environmental contamination is needed today across the globe. Soil is important for the healthy function of most ecosystems, the atmosphere, the lithosphere, and the hydrosphere, and also for the survival of humans on the planet. Most ecosystems are interlinked and mediate biota diversity and function. In this chapter we describe the tools and techniques that are most used for environmental impact analysis with respect to natural resource management.

## Role of Climate in Ecosystem Functions

Climate change is a current topic of discussion worldwide. In a nutshell, increasing the concentration of GHGs in the atmosphere increases the global temperature and affects ecosystem functions. Climate fluctuations and increases in GHGs adversely affect the productivity and potential functionality of an ecosystem, and thereby its efficiency. "Ecosystem function" is the technical term used to define the biological, geochemical, and physical processes, and their components, that occur within an ecosystem. It provides various services to humankind: regulatory, supportive, provisional, and cultural. The Ecosystem Service Framework lists 19 types of ecosystem function [19] (Table 1).

## Climate Change

Diversity and ecosystem services are the key areas that are vulnerable to climate change. In most scientific discussions, climate change has played a crucial role in agricultural production, management of forest productivity and processes, system efficiency of mechanical services related to directly or indirectly. Changes in the atmospheric concentrations of GHGs, aerosols, land cover and solar radiation alter the energy balance of the climate system and mediates the effects of climate change. In the preindustrial era, the global temperature increased as a result of increases in atmospheric concentrations of GHGs. This increase affects soils, kinetics of nutrient uptake by plants, soil-forming processes, ecosystem services, degradation of contaminants, and climatic events, among others. Rapid industrialization enhances the GHG emission rate, which is higher than what can be absorbed green plants or natural purifiers. The earth reflects solar (shortwave) radiation back to the atmosphere as longwave radiation. Because of the increasing concentration of GHGs in the atmosphere, the rate of reflection is decreasing and thereby increases the temperature. The measurement of global warming potential (GWP) is a primary factor in

**Table 1** Ecosystem function

| Ecosystem function category | Ecosystem function | Description |
|---|---|---|
| Regulating functions | Gas regulation | Balances the gas concentration in the atmosphere in relation to different soils and living processes |
| | Climate regulation | Regulates the weather and climatic phenomena; adjusts and creates microclimates governing different activities of crop production and plant and animal (including humans) lives and their functions |
| | Disturbance regulation | Maintains a soil's resilience |
| | Water regulation | Regulates spatial and temporal distributions of water |
| | Soil retention | Minimizes soil loss and soil degradation through natural and anthropogenic activities |
| | Nutrient regulation | Plant nutrient transport, storage, and recycling in different bio-geocycles |
| | Waste treatment and assimilation | Recycles organic and inorganic wastes |
| | Pollination | Interactions between plants and (1) biotic vectors (through insects and birds) and (2) abiotic vectors (through wind and water) |
| | Biological control | Naturally controls of insects and pests |
| | Barrier effect of vegetation | Reduces the soil and climate degradation by contaminants |
| Supporting functions | Supporting habitats | Provides suitable breeding and reproduction amenities to species |
| | Soil formation | Maintains the soil-forming process (e.g., rock to fine soil) |
| Provisioning functions | Food | Provides food for biota living on and within earth |
| | Raw materials | Provides raw materials for various industries |
| | Water supply | Provides water balance through different process (e.g., sediment trapping, infiltration, dissolution, precipitation, and diffusion) |
| | Genetic resources | Self-maintaining diversity of a system |
| | Provision of shade and shelter | Provides shade or shelter to plants, animals, and human beings |
| | Pharmacological resources | Provides pharmacological resources |
| Cultural functions | Landscape opportunity | Provides different extents and varieties of natural features and landscapes |

the exact assessment of global effects of climate change. The Intergovernmental Panel on Climate Change provides generally accepted values for GWP, which changed slightly between 1996 and 2001 [20]. The Intergovernmental Panel on Climate Change's 2001 Third Assessment Report provides an exact definition of how GWP is calculated. It is defined in relative mesures of a gas to trap heat from atmosphere in comparision to $CO_2$:

$$GWP(x) = \frac{\int_0^{TH} a_x \cdot [x(t)]dt}{\int_0^{TH} a_r \cdot [r(t)]dt}$$

where $TH$ is the time horizon over which the calculation is considered; $a_x$ is the radiative efficiency due to a unit increase in the atmospheric abundance of the substance, and $[x(t)]$ is the time-dependent decay in abundance of the substance following an instantaneous release of it at $t = 0$. The denominator contains the corresponding quantities of the reference gas (i.e., $CO_2$). The radiative efficiencies $a_x$ and $a_r$ are not necessarily constant over time. While the absorption of infrared radiation by many GHGs varies linearly with their abundance, a few important ones display nonlinear behavior for current and likely future abundances (e.g., $CO_2$, $CH_4$, and $N_2O$). For those gases, the relative radiative forcing will depend upon abundance and hence upon the future scenario adopted. Carbon dioxide has a GWP of exactly 1; it is the baseline unit to which all other GHGs are compared).

## Instrument Used to Measure GHGs Concentration

GHGs are the key component that affects the intensity of global climate change in various ecosystems. GHG concentrations are measured through the use of gas chromatography. It is a method using in analytical chemistry to separate and analyze compounds that can be vaporized without decomposing. This instrument is currently used to separate particular substances or separate compounds within a mixture. It is also used to prepare a pure compound from a heterogeneous mixture. A gas chromatograph has two phases: (1) the mobile phase, an inert gas that acts as the carrier (e.g., helium or nitrogen), and (2) the stationary phase, a microscopic layer of liquid or polymer on an inert solid support inside a piece of glass or metal tubing called a column. Gas samples are collected from the ecosystem into a static chamber (Fig. 1) and run on a gas chromatograph to categorize the compounds within them. In an agricultural crop production system, use efficiency of various inputs, or the production of GHGs by the inputs, is a key research parameter when selecting an input combination to enhance soil and crop productivity and conserve environmental health. As a result of large spatial and temporal variability—for example, GHG production and consumption in soil—a large number of replicating chambers are often required.

## Survey for Impact Analysis

Survey plays a crucial role in the assessment of any impact for a particular aspect. For example, in an environmental risk assessment, few sequential steps are needed for monitoring with respect to human health, that is, site characterization, exposure assessment, toxicity assessment, and risk characterization [21]. In all steps, the specific objective is to collect data for a particular region for a particular aspect.

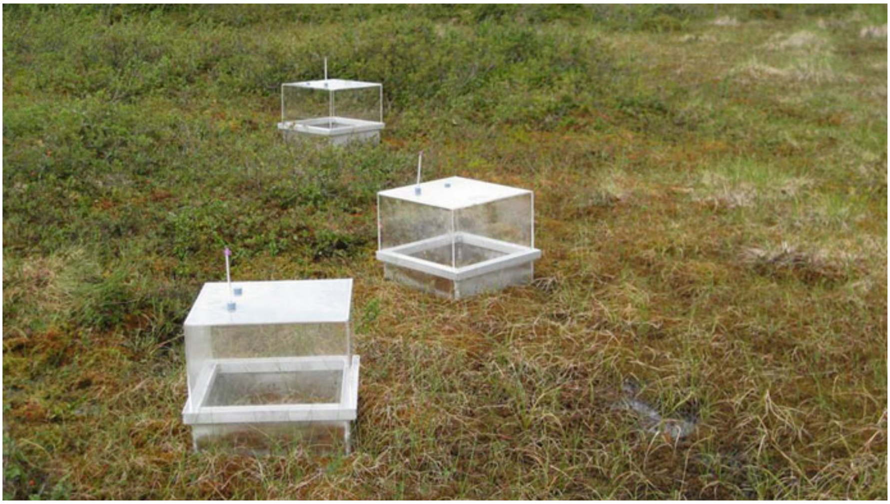

**Fig. 1** Static chamber use to collect samples

On the basis of statistical principles, survey is categorized into judgment-based and statistically based survey.

## Judgment Based

In this method, samples are taken on the basis of investigator knowledge as well as affected areas within the region. It is a simple task, and contamination in the environment can be quickly identified. It is, however, highly biased and is mostly used for preliminary investigation of a contaminant.

## Statistically Based

The statistical principles working in these survey methods are considered science-based procedure across the world [22]. These procedures have low risk of error by investigators. Two types of sampling are used. The first is *random sampling*, in which sampling points are chosen randomly, but not arbitrarily, from a region (Fig. 2a). Legitimate random-number generators are used to collect samples from a particular location. It can show the delineation boundary of contaminants, but has lower efficiency in identifying contaminants "hot spots." The second is *stratified sampling*, in which regions are divided into subareas based on the geomorphology or the different characteristics of regions (Fig. 2b). Each subarea is analyzed separately and concluded to be an individual site. This type of sampling is laborious, requires high skill, and makes the survey more expensive. It does, however, have higher reliability and avoids the risk of insufficient sampling data from polluted regions.

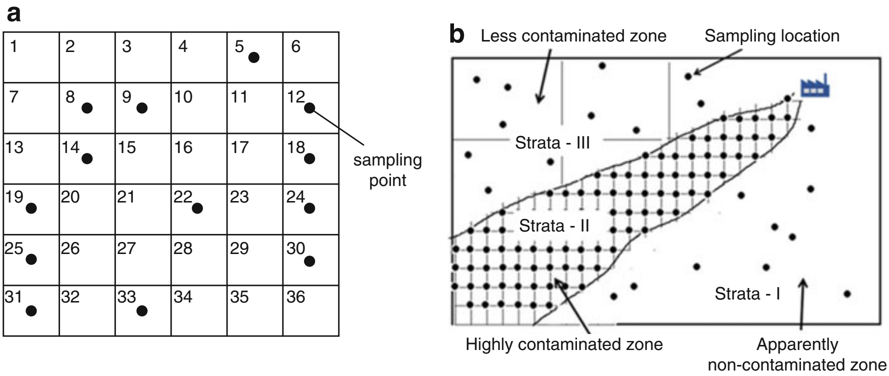

**Fig. 2** Schematic layout of sampling patterns: (**a**) random sampling and (**b**) stratified sampling

## Reasons for Sampling

Sampling is the key function of an impact analysis and determines the accuracy of its results. Sometimes, however, erroneous sampling can lead to misinterpretation of results and may convey the wrong message to investigating agencies.

## Sampling Procedure for Soil Fertility Evaluation

Crop production is affected by a soil's fertility and capacity to supply nutrients. Soil fertility and nutrient use efficiency are the key components in the evaluation of new methods of crop cultivation [5, 23] and development, and in an impact analysis of a new chemical molecule for crop production [24, 25]. A soil fertility evaluation requires predictions for targeted crop yields, categorization of soils, and an assessment of the types and degree of soil related constraints (e.g., salinity or alkalinity), and surface soil samples up to 15 cm in depth are needed. The samples should be taken in a zig-zag pattern to avoid human bias. In this procedure, four to six samples are collected from 1 ha of a crop field using an auger; and quartering & removes the two opposite portion of the soil samples. This process must be repeated until a 0.5 kg soil sample remains. When collecting soil samples, the following must be avoided:

- Bunds, heaps of FYM, chemical fertilizers, or agricultural inputs
- Use of bags or boxes previously used to store fertilizer or agricultural inputs
- Use of iron *khurpi* to sample micronutrients
- Mixing of different types of soil samples in a composite sample
  Apply the following guidelines when taking samples:
- Use stainless steel augers.
- Take a separate sample for each particular type of soil.

- Take a sample from a *V*-shaped hole after removing the top few centimeters of soil, debris, and crop residue. A depth of 15 cm is appropriate for most agricultural crops, but for plantation or deep-rooted crops it should go down to the depth of the roots.
- Properly label each sample and submit then to the laboratory with complete information: name of the farmer, location, soil type, crop history, date of sampling, agriculture input used, etc.

## Environment Impact Measurement Parameters

### Assessment of Soil Fertility Levels

Soil fertility and environmental services are interdependent and affect the interrelation of various ecosystems. Soil properties determine crop yield and soil productivity [26]. Soil samples are collected from the surface layer (down 15 cm) for most crops, but soil depth can be extended depending on the purpose and the type of crop. Horticultural crops need soil samples from various depths (15, 30, 60, 90 cm). After processing, soil samples are passed through a 2-mm sieve and used to analyze various properties. Some of the important instruments used to analyze soil properties are listed in Table 2, and associated methods of analysis are listed in Table 3.

#### pH

Soil pH is the one of the key parameters of soil fertility and the availability of plant nutrients essential for crop growth [103]. Soil pH is a measure of a soil's acidity and alkalinity. For analysis, soil and water at a ratio of 1:2 or 1:2.5 is prepared and the probes of a pH meter are placed into the soil–water mixture. Soil pH ranges from 0 to 14. In acidic soil, the pH measured with this method normally ranges between 4 and 6; a neutral pH is 6.5 to 7.5, and a pH $>7.5$ indicates an alkaline condition. These limits are further divided into various minor limits.

#### Electrical Conductivity

The electrical conductivity of soil is measured in a similar way as soil pH except in a clear supernatant and using an electrical conductivity meter. In this method, 0.01 *N* potassium chloride solution is used to standardize the instruments.

#### Organic Carbon

Organic carbon is greatly affected by climatic conditions as well as the crop patterns of a region. Soil organic carbon acts as an index of soil fertility and microbial activity in soil. On the basis of analysis, it is categorized as low ($<0.5\%$), medium (0.5–0.75%), and high ($>0.75\%$). It is analyzed through the use of the Walkley Black method [29], in which $K_2Cr_2O_7$ is used as an oxidation reagent and back-titrated with 0.5 N ferrous ammonium sulphate. Soil organic carbon values are directly related to the availability of plant nutrients in soil. Because of climatic variations,

**Table 2** Common instruments for measuring impact assessment related to natural resource management

| Instrument | Use in environmental impact assessment activities |
|---|---|
| pH meter | Soil reaction (acidity, alkalinity) |
| EC meter | Conductivity in soil |
| TOC analyzer | Organic carbon in soil |
| HPLC | Organic compounds in the ecosystem |
| CHNS | Carbon, nitrogen, sulfur and hydrogen in soil and plants |
| GC | Gaseous composition of the atmosphere |
| GM counter | Radioactivity in a system |
| AAS/ICP-OES | Metal concentration in a system |
| Flame photometer | Analysis of potassium, calcium and sodium |
| Flow injection nitrogen analyzer | Nitrogen analysis |
| Spectrophotometer | Phosphorus determination |
| MIR spectrophotometer | Soil fertility evaluation |
| TXRF | Soil fertility evaluation |
| Pressure plate apparatus | Capacity of a soil to hold water |
| Cone penetrometer | Soil hardness |
| Yoder apparatus/permeameter | Soil aggregates |
| IR gas analyzer | Respiration rate in plants |
| Mridaparikshak | Soil fertility assessment |
| COD meter | Chemical oxygen demand |
| BOD | Biological oxygen demand |
| Nitrogen auto-analyzer | Nitrogen content in a system |
| GPS | Identification of location |
| Munsell color chart | Color of a soil |
| Bouyoucos hydrometer | Soil texture |
| Tensiometer | Measurement of moisture in soil |
| G:C ratio, DNA hybridization, ribotyping, RISA, RAPD, metagenomics | Identification of soil biodiversity |

*AAS*, *BOD* biological oxygen demand, *CHNS*, *COD* chemical oxygen demand, *EC* electrical conductivity, *G:C*, *GC* gas chromatography, *GM Geiger Muller*, *GPS* global positioning system, *HPLC* high-performance liquid chromatography, *ICP-OES* inductively coupled plasma optical emission spectrometry, *IR* infrared, *MIR*, *RAPD* random amplification of polymorphic DNA, *RISA* ribosomal intergenic spacer analysis, *TOC total organic C*, *TXRF total reflection X-ray fluorescence*

plants vary their secretion of root exudates. Carbon accumulated in soil could be measured through the use of this procedure [37].

## Available Nitrogen

Easily mineralizable nitrogen is estimated using alkaline 0.32% $KMnO_4$. It oxidizes organic matter present in soil and liberates nitrogen in an ammonical form, which is

**Table 3** Common techniques/methods for an impact assessment related to natural resource management

| Method | Used in environmental impact assessment activities |
|---|---|
| pH (soil-to-water ratio, 1:2.5) | Jackson [27] |
| EC (soil-to-water ratio, 1:2.5) | Jackson [27] |
| Texture | Bouyoucos [28] |
| Organic carbon | Walkley and Black [29] |
| Available phosphorus | Olsen et al. [30, 31] |
| Available nitrogen | Subbiah and Asija [32] |
| Available potassium | Jackson [27] |
| DTPA extractable micronutrient | Lindsay and Norvell [33] |
| Ca + Mg | Singh et al. [26] |
| DHA | Casida et al. [34] |
| Alkaline and acidic phosphatases | Tabatabai and Bremner [35] |
| FDA | Adam and Duncan [36] |

*DHA dehydrogenase activity*, *DTPA* diethylenetriamine penta-acetic acid, *EC* electrical conductivity, *FDA fluorescein diacetate*

absorbed in 2% boric acid solution. The boric acid is back-titrated with 0.02 *N* $H_2SO_4$. This method was first described by Subbiah and Asija [32].

### Available Phosphorus

Worldwide, the method described by Bray and Kurtz [31] is used to measure phosphorus in soil with a lower pH soil (acidic conditions), and that described by Olsen et al. [30] used in soil with a higher pH. In the first method, the soil extraction solution comprises 0.03 *N* $NH_4F$ and 0.025 *N* HCl, whereas the method by Olsen et al. uses a 0.5 *M* $NaHCO_3$ solution at pH 8.5 during analysis.

### Available Potassium

Potassium is also a major plant nutrient that determines the crop yield potential of a cultivar. It also acts against insect pests that attach to crops. It is measured in soil using the method described by Hanway and Heidel [38], using 1 *N* ammonium acetate (pH 7.0) as a extractant.

### Micronutrients

Most cationic micronutrients (Cu, Ni, Zn, Mn, Fe) are analyzed using the method described by Lindsay and Norvell [33]; boron, by a hot water method [39]; and molybdenum, based on work by Singh et al. [26].

## Assessment of Heavy Metals

### Estimation of Available Concentration of Metals

The available concentration of a metal is directly responsible for its toxicity. In terms of plant nutrients, it is an index of soil fertility and affects crop yields. In the case of heavy metals, their concentrations show the negative potential of a metal to effect crop growth and development [40]. A range of extractants are used to estimate metals in soil. Among these, diethylenetriamine penta-acetic acid is a common extractant used in most soil laboratories to measure available metal in soils. A known quantity of soil is extracted using diethylenetriamine penta-acetic acid (DTPA) with shaking for 2 h. The main precaution during this extraction is that the soil to extractant ratio must be 1:2. After filtration, the concentrations of available metals in the soil are measured through the use of inductively coupled plasma optical emission spectrometry (ICP-OES).

### Digestion for Total Metal Estimation

The total concentrations of metals in soil samples are used to compute various indices related to metal accumulation as a result of anthropogenic activities. A known amount of soil is digested with aqua regia, a diacid mixture, or a triacid mixture. During digestion, 5 mL $HNO_3$ is added to the soil samples for predigestion and kept overnight. Then, 10 mL aqua regia ($HCl:HNO_3$ [3:1]), a diacid ($HNO_3$: $HClO_4$ [9:4]), or a triacid ($HNO_3:H_2SO_4:HClO_4$ [10:1:4]) is added for proper digestion and kept on a hot plate until proper digestion occurs. The white color of the digested samples indicates proper digestion. The sample is removed from the hot plate and the final volume is prepared. The concentrations of metals are measured using ICP-OES.

### Heavy Metals Measurement by ICP-OES

A range of instruments and methods are available for determining heavy metal concentrations in ecosystem components. The most common is ICP-OES (Fig. 3). This process uses a fourth state of matter—that is, plasma—with a temperature of 6000–7000 kelvin (K); the inner core, known as the induction zone, can reach a temperature up to 10,000 K. The liquid sample is inserted into the ICP-OES using

**Fig. 3** Inductively coupled plasma optical emission spectrometry

peristaltic pump through a nebulizer into a spray chamber. Argon gas plays a crucial role in the generation of plasma, which occurs at the end of a quartz torch. During this process, a high-frequency alternating current and a water-cooled induction coil are properly controlled by the instrument. The injected analyzing solution from a nebulizer and electrons of the metal take thermal energy and reach a higher, “excited” state. After a few moments, electrons reduce their thermal energy and revert to the original ground state and liberate a particular spectrum. Each metal has its own spectrum. Using Echelle grating, a prism and focusing mirror capture the emitted spectrum through a charge-coupled device.

This instrument has very low chemical interference and is reproducible. More than 70 metals and earth metals can be measured with ICP-OES. Simultaneous and sequential analysis of multiple elements is possible, with high sensitivity. The running and maintenance costs of the instruments are high, and skilled manpower is required during the analysis.

## Assessment of Soil Biological Activities

### Assessment of Soil Enzymatic Activities

Soil enzymatic activities affect soil fertility and the capacity of soil to supply essential plant nutrients. Different types of soil enzymes are produced by microorganisms in the soil and are mediated by the external application of agricultural inputs and contaminants. Soil enzymes take part in initiating and maintaining biogeochemical cycles of plant nutrients and provide the basic support for fertility to achieve the healthy development of plants [41]. They also increase the reactive area to decompose soil organic matter and detoxify trace metals [42]. The addition of organic residue in contaminated soil reduces the soil’s pH and enhances the nutrient availability [43–47]. Decomposition of organic matter releases various types of organic acids and improves soil health [48–51]. During decomposition, microbes take carbon from crop residue and multiply their population, producing a significant amount of organic acids [52, 53]. However, a higher concentration of organic acids enhances soil aggregation and crop productivity. Different tools and techniques are used for impact assessments of organic residues on soil enzyme activities and carbon sequestration; these are key researchable issues in agriculture [54–58]. Some important soil enzymes are listed in Table 4 [59, 60].

### Environmental Impact Assessment in Relation to Soil Biodiversity

Soil biodiversity is a main force that affects nutrient dynamics, degradation of various contaminants, and secretion of plant growth–promoting substances in a soil system [61]. Soil biodiversity refers to a variety of species within the soil ecosystem that form a web of biological activities. Increasing the contaminants in a soil affects biodiversity in terms of types and populations of soil biota [62]. Soil biodiversity is mainly a count of fungi, bacteria, actinomycetes, and other small animals in a soil. During an environmental impact analysis, soil diversity is studied to identify precisely the direct and indirect effects of contaminants on soil microbial

**Table 4** Soil enzymes involved in nutrient dynamics

| Enzyme | Substances acted on in organic matter | End product | Biological significance | Predictor of soil function |
|---|---|---|---|---|
| Enzyme for hydrogen transfer to a variety of substrates | | | | |
| Dehydrogenase | Hydrogen-donating and -accepting species ($CO_2$, organic acids, alcohols, etc.) | Oxidized or reduced products | Microbial electron transport system, proton release | General index of microbial activity |
| Enzyme for decomposition of carbon substrates | | | | |
| α-Amylase | Starch | Dextrins | Release of Carbon compounds required for growth of microbes | OM decomposition |
| β-Amylase | Starch | Maltose | | OM decomposition |
| Maltase | Maltose | Glucose | | OM decomposition |
| Cellulase | | | | |
| Endocellulase | Cellulose | Cellodextrins | | OM decomposition |
| Exocellulase | Cellulose | Cellobiose, cellotriose | | OM decomposition |
| β-Glucosidase | Cellobiose, cellotriose | Glucose | | General index of microbial activity |
| Pectinase | Pectin | Oligosaccharides | | OM decomposition |
| Lignases | | | | |
| Lignin peroxidase | Lignin | Partially depolymerized lignin | | OM decomposition |
| Manganese peroxidase | Lignin | Partially depolymerized lignin | | OM decomposition |
| Laccase | Lignin | Mixture of aliphatic and aromatic polymers | | OM decomposition |
| Enzymes for decomposition of nitrogen substrates | | | | Nutrient cycling |
| Protease | Protein | Amino acids | Nitrogen source for soil microbes | |
| Deaminase or ammonia lyase | Amino acids | Ammonia + organic acids | Nitrogen nutrition of plants and soil microbes | |
| Nitrate reductase | Nitrates | Ammonia | | |
| Amidase | Nitrogen-carbon bonds of | Ammonium ($NH_4$) | | |

(*continued*)

**Table 4** (continued)

| Enzyme | Substances acted on in organic matter | End product | Biological significance | Predictor of soil function |
|---|---|---|---|---|
| | nonproteinaceous organic nitrogen compounds | | | |
| Urease | Urea | Ammonia and carbon dioxide | | |
| Enzymes for decomposition of phosphorus substrates | | | | Nutrient cycling |
| Acid phosphomonoesterase | Organic phosphorus compounds | Orthophosphate | Phosphorus source for plants and soil microbes | |
| Alkaline phosphomonoesterase | Organic phosphorus compounds | Orthophosphate | | |
| Phosphodiesterases | Nucleic acids and other organic phosphorus compounds with phosphate interlinks | Orthophosphate | | |
| Phytases | Phytin | Orthophosphate | | |
| Enzyme for decomposition of sulfur substrates | | | | |
| Sulfatase | Organic sulfur compounds like sulfur-containing amino acids | Sulphate | Sulfur source for plants and soil microbes | Nutrient cycling |

diversity. Two methods are used in practice: (1) viable and (2) culturable. In this era of technological advancement, various molecular tools and techniques are used to extract and measure nucleic acids in soil systems. These save time, are more accurate, and easily identify the species, genera, families, or higher taxonomic classes in complex soils. These tools are important in categorizing microbial variability within species to diversity of communities [63]. Some of the processes involved in the identification of soil biodiversity are molecular tools and techniques.

## G:C Ratio

The G:C ratio is the ratio of percentages of guanine (G) and cytosine (C) in DNA. It is measured using chromatographic methods. The G:C ratio of prokaryotes commonly falls between 20% and 80%.

## DNA Hybridization

The G:C ratio does not clearly identify the nucleotide sequence of DNA. Hybridization measures the degree of sequence similarity between two DNAs. In this technique, the DNA of an organism is isolated and mixed with a radioactive material

($^{32}$P or $^{3}$H), then denatured through heating and mixed with the DNA of another organism, which is not radioactive. The technique is too sensetive to identify the genera of the two organisms [64].

### Ribotyping

Ribotyping is useful for measuring the unique sequence generated during digestion of the DNA of a particular organism. Here, different restriction enzymes are used for different patterns during the ribosomal RNA probe.

### Multilocus Sequence Typing

Multilocus sequence typing helps to identify the sequence of the same gene set from different strains of a particular organism.

### Ribosomal Intergenic Spacer Analysis

Ribosomal intergenic spacer analysis is involved in polymerase chain reaction (PCR) amplification of a particular part of the intergenic space situated between the 16S and 23S ribosomal subunits.

### Random Amplified Polymorphic DNA

This is good practice for using molecular markers to identify genetic diversity. In this technique, a random amplified polymorphic DNA band generated by an organism is compared with that of another organism by following a similar procedure of identification.

### Length Heterogeneity PCR

This method is similar to terminal restriction fragment-length polymorphism except the latter detects variation in amplicon length during restriction digestion. It also works on the basis of natural polymorphisms that occur as a result of mutation within a gene [65].

### Metagenomic Approach

This has helped to identify the collective genomes of an entire community within a particular boundary. It is an emerging field of research known as community genomic or environmental genomics. It was first used by Handelsman et al. [104] at the University of Wisconsin. It is now popular in advanced research laboratories across the world.

## Regulation with Respect to Heavy Metal Entry into Agricultural Land

Most developing countries use contaminated waste water for irrigation in periurban areas [66–69]. Waste water has huge water potential and contains organic carbon and plant nutrients for plant growth [70]. The long-term application of contaminated water has accumulated significant amounts of toxic metals and contaminated loads in

**Table 5** Maximum allowable concentrations of trace elements in soils of various countries (mg $kg^{-1}$)

| Countries | Cd | Cr | Cu | Ni | Pb | Zn | As | Hg |
|---|---|---|---|---|---|---|---|---|
| Austria | 5 | 100 | 100 | 100 | 100 | 300 | 50 | 5 |
| Poland | 1–3 | 50–80 | 30–70 | 30–75 | 70–150 | 100–300 | 30 | 5 |
| Germany | 1.5 | 100 | 60 | 50 | 100 | 200 | 20 | 1 |
| Russia | – | 0.05 ($Cr^{6+}$) | 23 (soluble pool) | 35 | 20 | 110 | 2 | 2.1 |
| United Kingdom | 3–15 | – | 50 | 20 | 500–2000 | 130 | 10 | – |
| United States | 20 | 1500 | 750 | 210 | 150 | 1400 | – | 8 |
| European Commission | 1–3 | 50–150 | 50–140 | 30–75 | 50–300 | 150–300 | – | 1–1.5 |

soils [45], which adversely affect the carbon mineralization rate and enzymatic activity in the soil. Application of chromium at more than 10 mg $kg^{-1}$ through $K_2Cr_2O_7$ reduced the mineralization rate in Vertisol in central India [71]. Chaney et al. [105] reported that application of Cd in soil reduced the microbial respiration rate and carbon mineralization rate in black oak forest soils. Application of Cr in soil reduced the activities of soil enzymes such as DHA, acid and alkaline phosphatases [71]. The cultivation of crops in metal-contaminated soils reduced the percentages of germination and root and shoot growth in wheat [72] and pigeon pea [73]. The concentration of metals reduces the secretion of root exudates from and affects the kinetics of nutrient uptake by plants[74]. Rhizodeposition is a boon for the plant growth, and it enhances the macro- and micronutrient efficiency in soil [75, 76]. These low-molecular organic acids provide a source of carbon for soil microorganisms [77–79]. Some microbes degrade toxicants into nontoxic forms, reducing toxicity [62]. Enhanced soil microbial population and diversity is mostly responsible for nutrient mineralization, contaminant degradation, and plant growth–promoting substance secretion in soil. Kabata-Pendias [80] described the maximum allowable metal concentrations in soil, by country (Table 5).

## Assessment of Metal-Contaminated Soils

### Metal Enrichment Factor

Heavy metal accumulation in soil causes deterioration of soil fertility and reductions in soil biota. Increasing concentrations in soil can be quantified by the metal enrichment factor (MEF), which identifies and quantifies anthropogenic interference in natural cycles of metal elements. Through the use of the MEF, a ratio is computed between the elevated level of metal in the soil, as caused by human interference, and the geogenic concentration [81–84]. The concentration of a particular metal in the soil and earth's crust, the geogenic concentration acts as a reference metal concentration when calculating the MEF. In most cases, Al, Sc, Ti, Fe, Mn, and Sr are used

**Table 6** Metal enrichment factor values with respect to contamination

| MEF Class | Interpretation |
|---|---|
| <2 | Deficient mineral enrichment |
| 2–5 | Moderate enrichment |
| >5–20 | Significant enrichment |
| >20–40 | Very high enrichment |
| >40 | Extremely high enrichment |

to compute the MEF because of their higher concentrations in the earth's crust and because they are not easily altered by human activities [85, 86]. As an example, an MEF can be calculated using aluminum [Al] as the reference, with the following relation:

$$\mathrm{MEF} = \frac{\left(\frac{X}{Al}\right) sample}{\left(\frac{X}{Al}\right) crust}$$

where $\left(\frac{X}{Al}\right) sample$ and $\left(\frac{X}{Al}\right) crust$ refer to the ratio of the mean concentration (milligrams per kilogram) of the target metal ($X$) and that of aluminum in the sediment and continental crust, respectively. On the basis of computed values, MEFs are categorized into five major classes [86] (Table 6).

## Geo-accumulation Index

The geo-accumulation index ($\mathrm{I_{geo}}$) depicts metal contamination currently with respect to preindustrial concentrations. To calculate $\mathrm{I_{geo}}$, a control field concentration is used as a reference value, or a preindustrial value can be used. This index is simple and it is easy to calculate metal accumulation over a period of industrial or anthropogenic activities.

$$I_{geo} = \log_2 \frac{C_n}{1.5 B_n}$$

where $C_n$ represents the concentration of a particular metal in the soil, whereas $B_n$ denotes the concentration of that same metal in the earth's crust [87]. The metal concentration accepted as the background is multiplied by the constant 1.5 in order to take into account natural fluctuations of a given substance in the environment and a very small anthropogenic influence (Table 7).

## Case Study

Kanpur is a city of leather: more than 500 small and medium-sized tanneries are located in and around the city. Local peoples living in this area are perform tanning processes within their households. A huge volume of tannery effluent is generated and, after undergoing certain treatments, this is used for irrigation to produce crops.

**Table 7** Geo-accumulation index values with respect to contamination [84, 88]

| $I_{geo}$ value | Class | Interpretation |
|---|---|---|
| $<0$ | I | Practically uncontaminated/unpolluted |
| 0–1 | II | Uncontaminated/unpolluted to moderately contaminated/polluted |
| $>1$–2 | III | Moderately contaminated/polluted |
| $>2$–3 | IV | Moderately to heavily contaminated/polluted |
| $>3$–4 | V | Heavily contaminated/polluted |
| $>4$–5 | VI | Heavily to very heavily contaminated/polluted |
| $>5$ | VII | Very heavily contaminated/polluted |

**Table 8** Nemerow pollution index ($P_n$)

| Class | Index | Interpretation |
|---|---|---|
| I | $P_n < 0.7$ | Safety domain |
| II | $0.7 \leq P_n < 1.0$ | Precaution domain |
| III | $1.0 \leq P_n < 2.0$ | Slightly polluted domain |
| IV | $2.0 \leq P_n < 3.0$ | Moderately polluted domain |
| V | $P_n > 3.0$ | Seriously polluted domain |

It contains the toxic metal chromium, which is known to be carcinogenic human beings [89]. Long- term application of the effluent accumulated a significant amount of total chromium in the soil and affected soil fertility and crop productivity. A geo-referenced survey was conducted to assess the effluent's impact on soil metal content, and soil and effluent samples were collected. Samples were analyzed using ICP-OES after digestion with aqua regia. The analyzed data fit into the $I_{geo}$ and were categorized into various classes of contamination. The results indicated that chromium accumulation in the soil was 28–30 times more than in soils irrigated with a tube well [90]. The concentration of chromium in the effluent was less, but long- term irrigation deposited a meaningful amount in the soil. The $I_{geo}$ was calculated per the equation developed by Muller [91]:

$$I_{geo} = \log_2 \frac{C_n}{1.5B_n}$$

where $C_n$ is the trace metal concentration in soil and $B_n$ is the geochemical baseline.

In this study, agricultural fields irrigated with tannery effluent was classified as class VII, meaning it was heavily to extremely contaminated/polluted [92].

### Nemerow Pollution Index

The Nemerow pollution index is mainly used in cases of single-metal contamination due to mining or industrial activities in a particular area. It provides the degree of soil ecological pollution and a potential assessment of ecosystem function and quality [93–95].

It is categorized into five classes (Table 8).

**Table 9** Modified Nemerow pollution index ($P_n$) (Guan et al. [93])

| Class | Index | Interpretation |
|---|---|---|
| 0 | $0 < P_n < 0.5$ | Uncontaminated |
| I | $0.5 < P_n \leq 1.0$ | Uncontaminated to moderately contaminated |
| II | $1.0 < P_n \leq 2.0$ | Moderately contaminated |
| III | $2.0 < P_n \leq 3.0$ | Moderately to heavily contaminated |
| IV | $3.0 < P_n \leq 4.0$ | Heavily contaminated |
| V | $4.0 < P_n \leq 5.0$ | Heavily to extremely contaminated |
| VI | $P_n > 5.0$ | Extremely contaminated |

**Table 10** Limits for contamination indices

| Contamination limits | Contamination index ($P_i$) | Integrated contamination index ($P_c$) |
|---|---|---|
| None | $P_i \leq 1$ | $P_c \leq 0$ |
| Low | $1 \leq P_i \leq 2$ | $0 < P_c \leq 7$ |
| Moderate | $2 \leq P_i \leq 3$ | $7 < P_c \leq 21$ |
| High | $P_i > 3$ | $P_c > 21$ |

Guan et al. [93] later modified the index and replaced single-metal contamination with the $I_{geo}$, per the formula:

$$P_n = \sqrt{\left(I_{geomax}^2 + I_{geoave}^2\right)/2}$$

where, $I_{geomax}$ is the maximum $I_{geo}$ value and $I_{geoave}$ is the arithmetic mean of $I_{geo}$. This modification is described in Table 9.

### Integrated Contamination Index

The integrate contamination index ($P_c$) is also an important index for assessing contamination load in natural systems. It defined as the sum of 1 + the difference between the contamination index ($P_i$) for each metal:

$$P_C = \sum_{n}^{i=1} (P_i - 1)$$

The mean and standard deviation of $P_c$ were used to establish confidence intervals. Accordingly, a $P_c$ × distance curve was adjusted using a log scale for real distance. Terminology to describe the contamination index ($P_i$) and integrated contamination index ($P_c$) is defined in Table 10.

## Assessment of Heavy Metal Content in Plant Parts

For heavy metals analysis, a diacid mixture ($HNO_3$:$HClO_4$ at the ratio 9:4) was used to digest plant samples [96], and metals present in the plant extractant were analyzed using ICP-OES.

For example, crop plant parts contaminated by chromium were harvested and various ratios of metal accumulation were computed. Parameters such as bioconcentration factor (BCF), translocation factor (TF), translocation efficiency (TE), and crop removal capacity could be computed as described below.

i. BCF defines the capacity of the plant to remove contaminants and is calculated by the formula [97]

$$BCF = \frac{\mathrm{Cr}_{\text{harvested tissue}}}{\mathrm{Cr}_{\text{soil}}}$$

where, $\mathrm{Cr}_{\text{harvested tissue}}$ is the concentration of chromium in the harvested plant parts (roots, shoots), and $\mathrm{Cr}_{\text{soil}}$ is the concentration of chromium in the soil after respective treatments.

ii. TF refers to the transfer of chromium metal ions from root to shoot and is quantified by the formula proposed by Adesodun et al. [98]:

$$TF = \frac{\mathrm{Cr}_{\text{shoot}}}{\mathrm{Cr}_{\text{root}}}$$

where $\mathrm{Cr}_{\text{shoot}}$ and $\mathrm{Cr}_{\text{root}}$ are the concentrations of chromium in the root and shoot, respectively.

iii. TE was calculated from the formula described by Meers et al. [99]:

$$TE\ (\%) = \frac{\mathrm{Cr}_{\text{content in shoot}}}{\mathrm{Cr}_{\text{content in whole plant}}} \times 100$$

iv. Chromium removal represents the capacity of the crop to remove chromium and was calculated with the formula:

$$Cr\ removal\ (\%) = \frac{\text{Total Cr uptake by plant}}{\text{Total Cr applied to soil}} \times 100$$

## Urban Solid Waste: Use and Management

Because of limited natural resources, a pressing need exists for increased grain production to fill the hungry mouths of the growing population. Soil and water are both important natural resources and affect the quality of the environment and ecological services on earth. Maintaining the quality of natural resources and producing the necessary quantities of grains are big challenges to researchers and policymakers. The quantity of waste and the amount generated per capita within urban areas are increasing, posing a considerable and quickly growing challenge in their management. Long-term application of municipal/industrial effluents for irrigation or of composts prepared from municipal waste for crop production contaminated the soil and water bodies in agricultural areas [100, 101]. These waste materials contain huge volumes of organic matter and essential plant nutrients [66, 102 ]. However, they also contain contaminants in the form of heavy metals, microbes, organic and inorganic material, and so on. The introduction of toxic chemicals into soils has disturbed natural ecological processes, threatening the agro-ecosystem.

## Collection and Disposal of Municipal Solid Waste

### Solid Waste Collection and Disposal

Solid waste collection and disposal are very tough practices in developing countries like India. In ideal solid waste management, one of the cheapest and common waste management practices in many parts of the world is land filling. The majority of Indian cities collect waste through community bins and dump them in landfill areas; a small fraction of uncollectible municipal solid waste (MSW) lies along roadsides.

### Compost Preparation

Composting is an environmentally friendly method of MSW disposal and allows further wealth to be generated from the waste. In this process, collected MSW needs to be properly segregated to obtain the biodegradable fraction, which is composted and, after decomposition, disposed of in agricultural land. The biodegradable fractions should be used to prepare the compost. The presence of heavy metals is a big challenge to its use in agricultural crop production systems. A team headed by Dr. J. K. Saha, of the ICAR-Indian Institute of Soil Science in Bhopal, India, prepared MSW composts that had been collected from 34 manufacturers in 29 cities in India. On the basis of fertilizer index and clean index, the team categorized their potential use in agricultural crops and forestry plants.

## Categorization of MSW Compost

After preparing the compost from MSW, it should be analyzed for heavy metal content and plant nutrient concentrations. Both parameters are vary widely because of the variation in MSW generation from different cities.

### Fertilizer Index

The manurial (including plant nutrients) in MSW composts can be calculated on the basis of the fertilizer index using the formula:

**Table 11** Criteria for assigning the weighing factor to fertility parameters and the score value to analytical data

| Parameters | Score value ($S_i$) | | | | | Weighing factor ($W_i$) |
|---|---|---|---|---|---|---|
| | 5 | 4 | 3 | 2 | 1 | |
| Total organic carbon (%) | >20.0 | 15.1–20.0 | 12.1–15.0 | 9.1–12.0 | <9.1 | 5 |
| Total nitrogen (%) | >1.25 | 1.01–1.25 | 0.81–1.00 | 0.51–0.80 | <0.51 | 3 |
| Total phosphorus (%) | >0.60 | 0.41–0.60 | 0.21–0.40 | 0.11–0.20 | <0.11 | 3 |
| Total potassium (%) | >1.00 | 0.76–1.00 | 0.51–0.75 | 0.26–0.50 | <0.26 | 1 |
| Carbon-to-nitrogen ratio | <10.1 | 10.1–15 | 15.1–20 | 20.1–25 | >25 | 3 |
| Respiration activity (mg $CO_2$-C/g VS d) | <2.1 | 2.1–6.0 | 6.1–10.0 | 10.1–15 | >15 | 4 |

$$\text{Fertilizer index} = \frac{\sum_{n}^{i=1} S_i W_i}{\sum_{n}^{i=1} W_i}$$

where $S_i$ is the score value of analytical data and $W_i$ is the weighing factor of the $i$th fertility parameter (Table 11).

## Clean Index

The clean index indicates the threat caused by the trace metals in MSW compost with respect to phytotoxicity and mammalian toxicity. The higher the value of the clean index, the lower the potential toxicity of the MSW compost (Table 12). Composts prepared from MSW from various cities are analyzed for heavy metal concentrations and were assessed for toxicity using the formula

$$\text{Clean index} = \frac{\sum_{n}^{j=1} S_j W_j}{\sum_{n}^{j=1} W_j}$$

where $S_j$ is the score value of analytical data and $W_j$ is weighing factor of the $j$th heavy metal.

## Practical Utility of MSW Compost on the Basis of Fertilizer Index and Clean Index

While the fertilizer index can be taken as a measure of nutrient supply potential, the clean index can be used by regulatory authorities to restrict the entry of heavy metals into sensitive components of the environment, such as agricultural land and water

**Table 12** Criteria for assigning a weighing factor to heavy metal parameters and a score value to analytical data

| Heavy metal (mg kg$^{-1}$) | Score value ($S_j$) | | | | | | Weighing factor ($W_j$) |
|---|---|---|---|---|---|---|---|
| | 5 | 4 | 3 | 2 | 1 | 0 | |
| Zn | <151 | 151–300 | 301–500 | 501–700 | 701–900 | >900 | 1 |
| Cu | <51 | 51–100 | 101–200 | 201–400 | 401–600 | >600 | 2 |
| Cd | <0.3 | 0.3–0.6 | 0.7–1.0 | 1.1–2.0 | 2.0–4.0 | >4.0 | 5 |
| Pb | <51 | 51–100 | 101–150 | 151–250 | 251–400 | >400 | 3 |
| Ni | <21 | 21–40 | 41–80 | 81–120 | 121–160 | >160 | 1 |
| Cr | <51 | 51–100 | 101–150 | 151–250 | 251–350 | >350 | 3 |

**Table 13** Classification of MSW composts for their marketability and use in agricultural crop production systems

| Class | | Fertilizer index | Clean index | Quality control compliance | Overall quality and area of application |
|---|---|---|---|---|---|
| Marketable classes | A | > 3.5 | > 4.0 | Complying for all heavy metal parameters | **Best quality**: High manurial value and low heavy metal content<br>Can be used for high-value crops and in organic farming |
| | B | 3.1–3.5 | > 4.0 | | **Very good quality**: Medium fertilizing potential and low heavy metal content |
| | C | > 3.5 | | | **Good quality:** High fertilizing potential and medium heavy metal content |
| | D | 3.1–3.5 | 3.1–4.0 | | **Medium quality:** Medium fertilizing potential and medium heavy metal content |
| Restricted classes | RU-1 | < 3.1 | – | | Low fertilizing potential but safe for the environment<br>Can be used as a soil conditioner |
| | RU-2 | ≥ 3.1 | > 4.0 | Complying for all heavy metal parameters | Can be used to grow nonfood crops<br>Requires periodic monitoring of soil quality if use repeatedly |
| | RU-3 | ≥ 3.1 | ≤ 4.0 | | Can be used only to develop lawns/gardens, or tree plantations in forestry (with one-time application) |
| The samples not falling under the above marketable and restricted use classes are not suitable for agricultural land application but can be used to rehabilitate degraded land. | | | | | |

bodies. On the basis of fertilizer index and clean index values, the following scheme to classify MSW composts has been proposed for use in different applications and to determine their suitability as a marketable product (Table 13).

The Indian Institute of Soil Science, Bhopal, India, has developed software for use by compost manufacturers and quality control officials that guides analysts using methods of analysis of MSW composts, evaluates their quality, and recommends safe and beneficial areas of application. This software can be downloaded free from the Indian Institute of Soil Science website at http://www.iiss.nic.in/Software.html.

## Conclusions

Environmental impact assessment is necessary to measure environmental consequences (positive and negative) for the execution, planning, formulation of policy, organization of events, and start of project activities for proposed actions in a particular area. The inventories for the impact assessment of natural resources are key to agricultural production systems. Precise and well-timed environmental impact analysis can minimize losses due to natural calamities. Frequent changes in weather events creates a lot of ambiguity in the execution and proper planning of agricultural production policies and research. A number of tools and techniques are involved in the assessment of soil fertility and contamination and the measurement of GHGs. These require a high initial investment as well as specific skills for particular impact assessments. Presently, environmental impact assessments are more valuable for developing countries because of their limited natural resources with respect to huge population pressure.

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## References

1. IAIA (1999) Principle of environmental impact assessment best practice. International Association for Impact Assessment- 1999. Archived from the original on 19/02/2018
2. Saha JK, Rajendiran S, Coumar MV, Dotaniya ML, Kundu S, Patra AK (2017) Soil and its role in the ecosystem. In: Saha JK et al (eds) Soil pollution – an emerging threat to agriculture. Springer, Singapore, pp 11–36. https://doi.org/10.1007/978-981-10-4274-4_2
3. Saha JK, Rajendiran S, Coumar MV, Dotaniya ML, Kundu S, Patra AK (2017) Impacts of soil pollution and their assessment. In: Saha JK et al (eds) Soil pollution – an emerging threat to agriculture. Springer, Singapore, pp 37–73. https://doi.org/10.1007/978-981-10-4274-4_3
4. IAIA (1994) Impact assessment interorganisational committee on guidelines and principles. in: guidelines and principles for social impact assessment. Environ Impact Assess 12(2):107–152
5. Meena BP, Tiwari PK, Dotaniya ML, Shirale AO, Ramesh K (2017) Precision nutrient management techniques for enhancing nutrient use efficiency. In: Elanchezhian R, Biswas AK, Ramesh K, Patra AK (eds) Advances in nutrient dynamics in soil plant system for improving nutrient use efficiency. New India Publishing Agency, New Delhi, pp 61–74

6. Saha JK, Rajendiran S, Coumar MV, Dotaniya ML, Kundu S, Patra AK (2017) Agriculture, soil and environment. In: Saha JK et al (eds) Soil pollution – an emerging threat to agriculture. Springer, Singapore, pp 1–9. https://doi.org/10.1007/978-981-10-4274-4_1
7. Meena BL, Meena RL, Kanwat M, Kumar A, Dotaniya ML (2017) Impact of climate change under coastal ecosystem & adoption strategies. In: Kumar PS, Kanwat M, Meena PD, Kumar V, Alone RA (eds) Climate change & sustainable agriculture. New India Publishing Agency, New Delhi, pp 55–66
8. Dotaniya ML (2015) Impact of rising atmospheric $CO_2$ concentration on plant and soil process. In: Mohanty M, Sinha NK, Hati KM, Chaudhary RS, Patra AK (eds) Crop growth simulation modelling and climate change. Scientific Publisher, Jodhpur, pp 69–86
9. Kundu S, Dotaniya ML, Lenka S (2013) Carbon sequestration in Indian agriculture. In: Lenka S, Lenka NK, Kundu S, Rao AS (eds) Climate change and natural resources management. New India Publishing Agency, New Delhi, pp 269–289
10. Dotaniya ML, Meena VD, Lata M, Meena BL (2017) Climate change impact on agriculture: adaptation strategies. In: Kumar PS, Kanwat M, Meena PD, Kumar V, Alone RA (eds) Climate change & sustainable agriculture. New India Publishing Agency, New Delhi, pp 27–38
11. Mandal A, Radha TK, Neenu S (2013) Impact of climate change on rhizosphere microbial activity and nutrient cycling. In: Lenka S, Lenka NK, Kundu S, Rao AS (eds) Climate change and natural resource management. New India Publishing Agency, New Delhi, pp 93–116
12. Dotaniya ML, Meena VD, Kumar K, Meena BP, Jat SL, Lata M, Ram A, Dotaniya CK, Chari MS (2016) Impact of biosolids on agriculture and biodiversity. Today and Tomorrow's Printer and Publisher, New Delhi, pp 11–20
13. Lenka S, Lenka NK, Kundu S, Rao AS (2013) Climate change and natural resource management. New India Publishing Agency, New Delhi
14. Dotaniya ML, Dotaniya CK, Sanwal RC, Meena HM (2018) $CO_2$ sequestration and transformation potential of agricultural system. In: Martínez L, Kharissova O, Kharisov B (eds) Handbook of ecomaterials. Springer. https://doi.org/10.1007/978-3-319-48281-1_87-1
15. Lenka S, Lenka NK, Chaudhary RS (2013) Climate change mitigation options in agriculture. In: Climate change and natural resource management. New India Publishing Agency, New Delhi, pp 195–214
16. Sharma PK, Sarkar D (2002) Soil survey and mapping. In: Sekhon GS, Chhonkar PK, Das DK, Goswami, Narayanasamy, Poonia SR, Rattan RK, Sehgal J (eds) Fundamental of soil science. Indian Soc Soil Sci, New Delhi, pp 55–70
17. Saha JK, Rajendiran S, Coumar MV, Dotaniya ML, Kundu S, Patra AK (2017) Major inorganic pollutants affecting soil and crop quality. In: Saha JK et al (eds) Soil pollution – an emerging threat to agriculture. Springer, Singapore, pp 75–104. https://doi.org/10.1007/978-981-10-4274-4
18. Saha JK, Rajendiran S, Coumar MV, Dotaniya ML, Kundu S, Patra AK (2017) Organic pollutants. In: Saha JK et al (eds) Soil pollution – an emerging threat to agriculture. Springer, Singapore, pp 105–135. https://doi.org/10.1007/978-981-10-4274-5
19. ESF (2018) Ecosystem services framework. http://www.ecosystemservicesseq.com.au/ecosystem-functions.html, assessed on 20 Feb 2018
20. IPCC (2001) In: Watson RT, the Core Writing Team (eds) Climate change 2001: synthesis report. Cambridge University Press, Cambridge, UK
21. Malherbe L (2001) Designing a contaminated soil sampling strategy for human health risk assessment. Eurolab/Eurachem International workshop "Sampling", Lisbonne
22. Saha JK, Rajendiran S, Coumar MV, Dotaniya ML, Kundu S, Patra AK (2017) Collection and processing of polluted soil for analysis. In: Saha JK et al (eds) Soil pollution – an emerging threat to agriculture. Springer, Singapore, pp 137–153. https://doi.org/10.1007/978-981-10-4274-6
23. Meena BP, Shirale AO, Dotaniya ML, Jha P, Meena AL, Biswas AK, Patra AK (2016) Conservation agriculture: a new paradigm for improving input use efficiency and crop productivity. In: Bisht JK, Meena VS, Mishra PK, Pattanayak A (eds) Conservation agriculture

conservation agriculture- an approach to combat climate change in Indian Himalaya. Springer, pp 39–69

24. Lenka S, Rajendiran, Coumar MV, Dotaniya ML, Saha JK (2016) Impacts of fertilizers use on environmental quality. In national seminar on environmental concern for fertilizer use in future" at Bidhan Chandra Krishi Viswavidyalaya, Kalyani on February 26, 2016
25. Meena VD, Dotaniya ML (2017) Climate change, water scarcity and sustainable agriculture for food security. In: Kumar PS, Kanwat M, Meena PD, Kumar V, Alone RA (eds) Climate change & sustainable agriculture. New India Publishing Agency, New Delhi, pp 123–142
26. Singh D, Chhonkar PK, Dwivedi BS (2005) Manual on soil, plant and water analysis. Westville, New Delhi
27. Jackson ML (1973) Soil chemical analysis. Prentice Hall of India Pvt Ltd, New Delhi, pp 38–56
28. Bouyoucos GL (1962) Hydrometer method improved for making particle size analysis of soils. Agron J 54:464
29. Walkley AJ, Black IA (1934) An examination of the Degtjaff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci 37:29–38
30. Olsen SR, Cole CV, Watanabe FS, Dean LA (1954) Estimation of available phosphorus in soils by extraction with sodium bicarbonate. US Depart Agric Circ No 939, Agric Depart, US
31. Bray RH, Kurtz LT (1945) Determination of total, organic and available form of phosphorus in soils. Soil Sci 59:39–45
32. Subbiah BV, Asija GL (1956) A rapid procedure for the determination of available nitrogen in soils. Curr Sci 25:259–260
33. Lindsay WL, Norvell WA (1978) Development of a DTPA soil test for zinc, iron, manganese and copper. Soil SciSoc Am J 42:421–448
34. Casida LE, Klein DA, Santoro T (1964) Soil dehydrogenase activity. Soil Sci 98:371–376
35. Tabatabai MA, Bremner JM (1969) Use of p-nitrophenyl phosphate for assay of phosphatase activity. Soil Biol Biochem 1:301–307
36. Adam G, Duncan H (2001) Development of a sensitive and rapid method for the measurement of total microbial activity using fluorescein diacetate (FDA) in a range of soils. Soil Biol Biochem 33:943–951
37. Kushwah SK, Dotaniya ML, Upadhyay AK, Rajendiran S, Coumar MV, Kundu S, Rao AS (2014) Assessing carbon and nitrogen partition i*n kharif* crops for their carbon sequestration potential. Natl Acad Sci Lett 37(3):213–217
38. Hanway JJ, Heidel H (1952) soil analysis methods as used in Iowa State College Soil Testing Laboratory. Iowa Agric 57:1–31
39. Gupta UC (1967) A simplified method for determining hot water soluble boron in podzol soils. Soil Sci 103:424–428
40. Dotaniya ML, Rajendiran S, Coumar MV, Meena VD, Saha JK, Kundu S, Kumar A, Patra AK (2017) Interactive effect of cadmium and zinc on chromium uptake in spinach grown on Vertisol of Central India. Int J Environ Sci Technol 15(2):441–448
41. Fang S, Liu J, Liu D, Xie B (2010) Enzymatic activity and nutrient availability in the rhizosphere of poplar plantations treated with fresh grass mulch. Soil Sci Plant Nutr 56(3):483–491
42. Pankhurst CE, Hawke BG, McDonald HJ, Kirkby CA, Buckerfield JC, Michelsen P, O'Brien KA, Gupta VVSR, Doube BM (1995) Evaluation of soil biological properties as potential bioindicators of soil health. Aus J Exp Agric 35:1015–1028
43. Dotaniya ML (2013) Impact of various crop residue management practices on nutrient uptake by rice-wheat cropping system. Curr Adv Agric Sci 5(2):269–271
44. Dotaniya ML, Datta SC (2014) Impact of bagasse and press mud on availability and fixation capacity of phosphorus in an Inceptisol of north India. Sugar Tech 16(1):109–112

45. Dotaniya ML, Datta SC, Biswas DR, Dotaniya CK, Meena BL, Rajendiran S, Regar KL, Lata M (2016) Use of sugarcane industrial byproducts for improving sugarcane productivity and soil health-a review. Int J Recycl Org Waste Agric 5(3):185–194
46. Dotaniya ML, Datta SC, Biswas DR, Kumar K (2014) Effect of organic sources on phosphorus fractions and available phosphorus in Typic Haplustept. J Indian Soc Soil Sci 62(1):80–83
47. Dotaniya ML, Kushwah SK, Rajendiran S, Coumar MV, Kundu S, Rao AS (2014) Rhizosphere effect of *kharif* crops on phosphatases and dehydrogenase activities in a Typic Haplustert. Natl Acad Sci Lett 37(2):103–106
48. Dotaniya ML, Datta SC, Biswas DR, Meena HM, Rajendiran S, Meena AL (2015) Phosphorus dynamics mediated by bagasse, press mud and rice straw in inceptisol of north India. Agrochimica 59(4):358–369
49. Dotaniya ML, Sharma MM, Kumar K, Singh PP (2013) Impact of crop residue management on nutrient balance in rice-wheat cropping system in an Aquic hapludoll. J Rural Agric Res 13(1):122–123
50. Dotaniya ML, Datta SC, Biswas DR, Meena BP (2013) Effect of solution phosphorus concentration on the exudation of oxalate ions by wheat (*Triticum aestivum* L.). Proc Natl Acad Sci India Sec B: Biol Sci 83(3):305–309
51. Singh VS, Meena SK, Verma JP, Kumrar A, Aeron A, Mishra PK, Bisht JK, Pattanayaka A, Naveed M, Dotaniya ML (2017) Plant beneficial rhizospheric microorganism (PBRM) strategies to improve nutrients use efficiency: a review. Ecol Eng 107:8–32
52. Dotaniya ML, Rajendiran S, Meena BP, Meena AL, Meena BL, Jat RL, Saha JK (2016) Elevated carbon dioxide ($CO_2$) and temperature vis- a-vis carbon sequestration potential of global terrestrial ecosystem. In: Bisht JK, Meena VS, Mishra PK, Pattanayak A (eds) Conservation Agriculture: an approach to combat climate change in Indian Himalaya. Springer, India, pp 225–256
53. Singh M, Dotaniya ML, Mishra A, Dotaniya CK, Regar KL (2016) Role of biofertilizers in conservation agriculture. In: Bisht JK, Meena VS, Mishra PK, Pattanayak A (eds) Conservation agriculture: an approach to combat climate change in Indian Himalaya. Springer, India, pp 113–134
54. Dotaniya ML, Kushwah SK (2013) Nutrients uptake ability of various rainy season crops grown in a Vertisol of central India. Afr J Agric Res 8(44):5592–5598
55. Meena VD, Dotaniya ML, Rajendiran S, Coumar MV, Kundu S, Rao AS (2013) A case for silicon fertilization to improve crop yields in tropical soils. Proc Natl Acad Sci India Sec B: Biol Sci 84(3):505–518
56. Prajapati K, Rajendiran S, Coumar MV, Dotaniya ML, Ajay KS, Saha JK, Patra AK (2016) Carbon occlusion potential of rice phytoliths: implications for global carbon cycle and climate change mitigation. Appl Ecol Environ Res 14(2):265–281
57. Prajapati K, Rejendiran S, Coumar MV, Dotaniya ML, Meena VD, Ajay KNK, Rawat AK, Kundu S (2014) Bio-sequestration of carbon in rice phytoliths. Natl Acad Sci Lett 38:129–133
58. Rajendiran S, Coumar MV, Kundu S, Ajay DML, Rao AS (2012) Role of phytolith occluded carbon of crop plants for enhancing soil carbon sequestration in agro-ecosystems. Curr Sci 103 (8):911–920
59. Das SK, Verma A (2011) Role of soil enzymes in maintaining soil health. In: Shukla G, Verma A (eds) Soil enzymology. Springer International, Berlin https://doi.org/10.1007/978-3-642-14225-3_2
60. Gianfreda L, Rao MA (2014) Enzymes in agricultural sciences. OMICS Group eBooks, Italy
61. Thakur JK, Sahu A, Singh UB, Mandal A, Manna MC (2015) Molecular techniques in soil biodiversity study. In: Microbial biodiversity a boon for agriculture sustainability. Biotech Books, New Delhi, pp 505–524
62. Mandal A, Thakur JK, Sahu A, Bhattacharjya S, Manna MC, Patra AK (2017) Plant–microbe interaction for the removal of heavy metal from contaminated site. In: Choudhary D, Varma A, Tuteja N (eds) Plant-microbe interaction: an approach to sustainable agriculture. Springer, Singapore
63. Johnsen K, Jacobsen CS, Torsvik V, Sorensen J (2001) Pesticide effects on bacterial diversity in agricultural soils-a review. Biol Fertil Soils 33:443–453

64. Madigan MT, Martinko JM (2006) Brock biology of microorganisms, 11th edn. Pearson Prentice Hall, USA
65. Mills DK, Entry JA, Gillevet PM (2007) Assessing microbial community diversity usingamplicon length heterogeneity polymerase chain reaction. Soil Sci Soc Am J 71:572–578
66. Meena VD, Dotaniya ML, Saha JK, Patra AK (2015) Antibiotics and antibiotic resistant bacteria in wastewater: impact on environment, soil microbial activity and human health. Afr J Microbiol Res 9(14):965–978
67. Rajendiran S, Dotaniya ML, Coumar MV, Panwar NR, Saha JK (2015) Heavy metal polluted Soils in India: status and countermeasures. JNKVV Res J 49(3):320–337
68. Saha JK, Rajendiran S, Coumar MV, Dotaniya ML, Kundu S, Patra AK (2017) Urban activities in india leading to soil pollution. In: Saha JK et al (eds) Soil pollution – an emerging threat to agriculture. Springer, Singapore, pp 193–228. https://doi.org/10.1007/978-981-10-4274-8
69. Saha JK, Rajendiran S, Coumar MV, Dotaniya ML, Kundu S, Patra AK (2017) Industrial activities in India and their impact on agroecosystem. In: Saha JK et al (eds) Soil pollution – an emerging threat to agriculture. Springer, Singapore, pp 229–249. https://doi.org/10.1007/978-981-10-4274-9
70. Saha JK, Panwar N, Srivastava A, Biswas AK, Kundu S, Rao AS (2010) Chemical, biochemical, and biological impact of untreated domestic sewage water use on Vertisol and its consequences on wheat (*Triticum aestivum*) productivity. Environ Monit Assess 161:403–412
71. Dotaniya ML, Rajendiran S, Meena VD, Saha JK, Coumar MV, Kundu S, Patra AK (2017) Influence of chromium contamination on carbon mineralization and enzymatic activities in Vertisol. Agric Res 6(1):91–96
72. Dotaniya ML, Das H, Meena VD (2014) Assessment of chromium efficacy on germination, root elongation, and coleoptile growth of wheat (*Triticum aestivum* L.) at different growth periods. Environ Monit Assess 186:2957–2963
73. Dotaniya ML, Meena VD, Das H (2014) Chromium toxicity on seed germination, root elongation and coleoptile growth of pigeon pea (*Cajanus cajan*). Legum Res 37(2):225–227
74. Bharti VS, Dotaniya ML, Shukla SP, Yadav VK (2017) Managing soil fertility through microbes: prospects, challenges and future strategies. In: Singh JS, Seneviratne G (eds). Springer, Agro-environmental sustainability, pp 81–111
75. Dotaniya ML, Datta SC, Biswas DR, Meena HM, Kumar K (2014) Production of oxalic acid as influenced by the application of organic residue and its effect on phosphorus uptake by wheat (*Triticum aestivum* L.) in an Inceptisol of north India. Natl Acad Sci Lett 37(5):401–405
76. Dotaniya ML, Prasad D, Meena HM, Jajoria DK, Narolia GP, Pingoliya KK, Meena OP, Kumar K, Meena BP, Ram A, Das H, Chari MS, Pal S (2013) Influence of phytosiderophore on iron and zinc uptake and rhizospheric microbial activity. Afr J Microbiol Res 7(51):5781–5788
77. Dotaniya ML, Meena BP (2017) Rhizodeposition by plants: a boon to soil health. In: Elanchezhian R, Biswas AK, Ramesh K, Patra AK (eds) Advances in nutrient dynamics in soil plant system for improving nutrient use efficiency. New India Publishing Agency, New Delhi, pp 207–224
78. Dotaniya ML, Meena HM, Lata M, Kumar K (2013) Role of phytosiderophores in iron uptake by plants. Agric Sci Dig 33(1):73–76
79. Dotaniya ML, Meena VD (2013) Rhizosphere effect on nutrient availability in soil and its uptake by plants -a review. Proc Natl Acad Sci India Sec B: Biol Sci 85(1):1–12
80. Kabata-Pendias A (2000) Trace element in soils and plants, 3rd edn. CRC Press, Baton Raton
81. Blaser P, Zimmermann S, Luster J, Shotyk W (2000) Critical examination of trace element enrichments and depletions in soils: As, Cr, Cu, Ni, Pb, and Zn in Swiss forest soils. Sci Total Environ 249:257–280
82. Dantu S (2009) Heavy metals concentration in soils of south-eastern part of Ranga Reddy district, Andhra Pradesh, India. Environ Monit Assess 149:213–222
83. Namaghi HH, Karami GH, Saadat S (2011) A study on chemical properties of groundwater and soil in ophiolitic rocks in Firuzabad, east of Shahrood, Iran: with emphasis to heavy metal contamination. Environ Monit Assess 174(1–4):573–583

84. Saha JK, Rajendiran S, Coumar MV, Dotaniya ML, Kundu S, Patra AK (2017) Assessment of heavy metals contamination in soil. In: Saha JK et al (eds) Soil pollution – an emerging threat to agriculture. Springer, Singapore, pp 155–191. https://doi.org/10.1007/978-981-10-4274-7
85. Saur E, Juste C (1994) Enrichment of trace elements from long-range aerosol transport in sandy podozolic soils of southwest France. Water Air Soil Pollut 73:235–246
86. Sutherland RA (2000) Bed sediment-associated trace metals in an urban stream, Oahu, Hawaii. Environ Geol 39:611–627
87. Taylor SR, Mclennan SM (1995) The geochemical evolution of the continental crust. Rev Geophys 33:241–265
88. Forstner U (1990) Contaminated sediments, Lecture notes in earth science. Springer, Berlin
89. Dotaniya ML, Thakur JK, Meena VD, Jajoria DK, Rathor G (2014) Chromium pollution: a threat to environment. Agric Rev 35(2):153–157
90. Dotaniya ML, Saha JK, Meena VD, Rajendiran S, Coumar MV, Kundu S, Rao AS (2014) Impact of tannery effluent irrigation on heavy metal build up in soil and ground water in Kanpur. Agrotechnology 2(4):77
91. Muller G (1969) Index of geoaccumulation in sediments of the Rhine river. Geo J 2:109–118
92. Dotaniya ML, Meena VD, Rajendiran S, Coumar MV, Saha JK, Kundu S, Patra AK (2017) Geo-accumulation indices of heavy metals in soil and groundwater of Kanpur, India under long term irrigation of tannery effluent. Bull Environ Contam Toxicol 98(5):706–711
93. Guan Y, Shao C, Ju M (2014) Heavy metal contamination assessment and partition for industrial and mining gathering areas. Int J Environ Res Public Health 11:7286–7303
94. Jie-liang C, Zhou S, You-wei Z (2007) Assessment and mapping of environmental quality in agricultural soils of Zhejiang Province, China. J Environ Sci 19:50–54
95. Saha JK, Rajendiran S, Coumar MV, Dotaniya ML, Kundu S, Patra AK (2017) Remediation and management of polluted sites. In: Saha JK et al (eds) Soil pollution – an emerging threat to agriculture. Springer, Singapore, pp 317–372. https://doi.org/10.1007/978-981-10-4274-12
96. Page AL, Miller RH, Keeney DR (1982) Methods of soil analysis. Part 2 – Chemical and microbiological properties. Agron Soc Am, Madison
97. Zhuang P, Yang QW, Wang HB, Shu WS (2007) Phytoextraction of heavy metals by eight plant species in the field. Water Air Soil Poll 184:235–242
98. Adesodun JK, Atayese MO, Agbaje TA, Osadiaye BA, Mafe OF, Soretire AA (2010) Phytoremediation potentials of sunflowers (*Tithonia diversifolia* and *Helianthus annus*) for metals in soils contaminated with zinc and lead nitrates. Water Air Soil Pollut 207:195–201
99. Meers E, Hopgood M, Lesage E, Vervaeke P, Tack FMG, Verloo M (2004) Enhanced phytoextraction: in search for EDTA alternatives. Int J Phytoremediation 6(2):95–109
100. Saha JK, Rajendiran S, Coumar MV, Dotaniya ML, Kundu S, Patra AK (2017) Impact of different developmental projects on soil fertility. In: Saha JK et al (eds) Soil pollution – an emerging threat to agriculture. Springer, Singapore, pp 251–269. https://doi.org/10.1007/978-981-10-4274-10
101. Saha JK, Rajendiran S, Coumar MV, Dotaniya ML, Kundu S, Patra AK (2017) Soil protection policy. In: Saha JK et al (eds) Soil pollution – an emerging threat to agriculture. Springer, Singapore, pp 373–382. https://doi.org/10.1007/978-981-10-4274-13
102. Saha JK, Rajendiran S, Coumar MV, Dotaniya ML, Kundu S, Patra AK (2017) Status of soil pollution in India. In: Saha JK et al (eds) Soil pollution – an emerging threat to agriculture. Springer, Singapore, pp 271–315. https://doi.org/10.1007/978-981-10-4274-11
103. Dotaniya ML, Meena VD, Basak BB, Meena RS (2016) Potassium uptake by crops as well as microorganisms. In: Meena VS, Maurya BR, Verma JP, Meena RS (eds) Potassium solubilizing microorganisms for sustainable agriculture. Springer, India, pp 267–280
104. Handelsman J (2004) Metagenomics: application of genomics to uncultured microorganisms. Microbiol Mol Biol Rev 68(4):669–685
105. Chaney WR, Kelly JM Strickland RC (1978) Influence of cadmium and zinc on carbon dioxide evolution from litter and soil from a black oak forest. J Environ Qual 20:115–119