Draft Study Material

Soil and Water Testing Laboratory Assistant

(QUALIFICATION PACK: Ref. Id. AGR/Q8102)

SECTOR: AGRICULTURE

Grade 12

विद्यया ऽमृतमश्नुते

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NCERT

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Preface

Vocational Education is a dynamic and evolving field, and ensuring that every student has access to quality learning materials is of paramount importance. The journey of the PSS Central Institute of Vocational Education (PSSCIVE) toward producing comprehensive and inclusive study material is rigorous and time-consuming, requiring thorough research, expert consultation, and publication by the National Council of Educational Research and Training (NCERT). However, the absence of finalized study material should not impede the educational progress of our students. In response to this necessity, we present the draft study material, a provisional yet comprehensive guide, designed to bridge the gap between teaching and learning, until the official version of the study material is made available by the NCERT. The draft study material provides a structured and accessible set of materials for teachers and students to utilize in the interim period. The content is aligned with the prescribed curriculum to ensure that students remain on track with their learning objectives. The contents of the modules are curated to provide continuity in education and maintain the momentum of teaching-learning in vocational education. It encompasses essential concepts and skills aligned with the curriculum and educational standards. We extend our gratitude to the academicians, vocational educators, subject matter experts, industry experts, academic consultants, and all other people who contributed their expertise and insights to the creation of the draft study material. Teachers are encouraged to use the draft modules of the study material as a guide and supplement their teaching with additional resources and activities that cater to their students' unique learning styles and needs. Collaboration and feedback are vital; therefore, we welcome suggestions for improvement, especially by the teachers, in improving upon the content of the study material. This material is copyrighted and should not be printed without the permission of the NCERT-PSSCIVE.

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Module 1
Preparation of Soil and Water Samples for Analysis

Module Overview

Soil and water testing is carried out to optimize crop production through fertilizer application and protecting the environment from excess fertilizers contamination. These analyses are achieved with the help of true representative soil and water samples. Careful and proper sampling techniques ensure a true representative sample. A true representative sample shows the actual condition of the area from which it is collected. A small amount of representative sample from the study area is used for the analysis of different soil and water properties. Precise analytical methods ensure reliable data and appropriate interpretation of the results of analysis. Therefore, soil and water testing on a regular basis (2-3 years interval) is desirable as it provides proper fertilizer recommendations based on realistic yield goals.

Learning Outcomes

After completing this module, you will be able to:

- Describe the requirements and steps for setting up a soil and water testing laboratory, including equipment, facilities, and standard operating procedures.
- Explain the methods for collecting and processing soil and water samples, ensuring proper sampling techniques, preservation, and preparation for accurate testing and analysis.

Module Structure

- Session 1: Setting up of Soil and Water Testing Laboratory
- Session 2: Collection and Processing of Soil and Water Samples

Session 1: Setting up of Soil and Water Testing Laboratory

The major objective of soil and water analysis laboratory is to determine the various fertilizers and their proportions for enhancing crop production. For setting up a soil and water testing laboratory, we require well-designed areas, appropriate equipment, appropriate methods of analysis, strict quality control and competent laboratory staff. In this session, we will study various aspects of setting up a soil and water testing laboratory.

1.1 Uses of a soil and water testing laboratory

These laboratories are used for:

- Testing various aspects of soil, manure and water.
- Providing recommendations for fertilizer dosage etc. based on different soil types and crops.
- Providing extension services to the farmers and other stakeholders.
- Advising methods for improving soil health.
- The soil testing must be done in every two to three years whereas water testing is need based.
- This facility may also be used for chemical analysis of fruits, vegetables etc.

The vocational students should preferably be taken to nearby soil and water testing laboratories for better understanding and learning. A state-of-the-art soil and water testing facility exists at ICAR-Indian Institute of Soil Science (IISS) Bhopal, Madhya Pradesh (Figure 1.1).

Fig.1.1: ICAR-Indian Institute of Soil Science, Bhopal

1.2 Various facilities in a soil and water testing laboratory

The soil and water testing laboratory houses various types of specialized rooms as shown in the floor plan Figure 1.2.

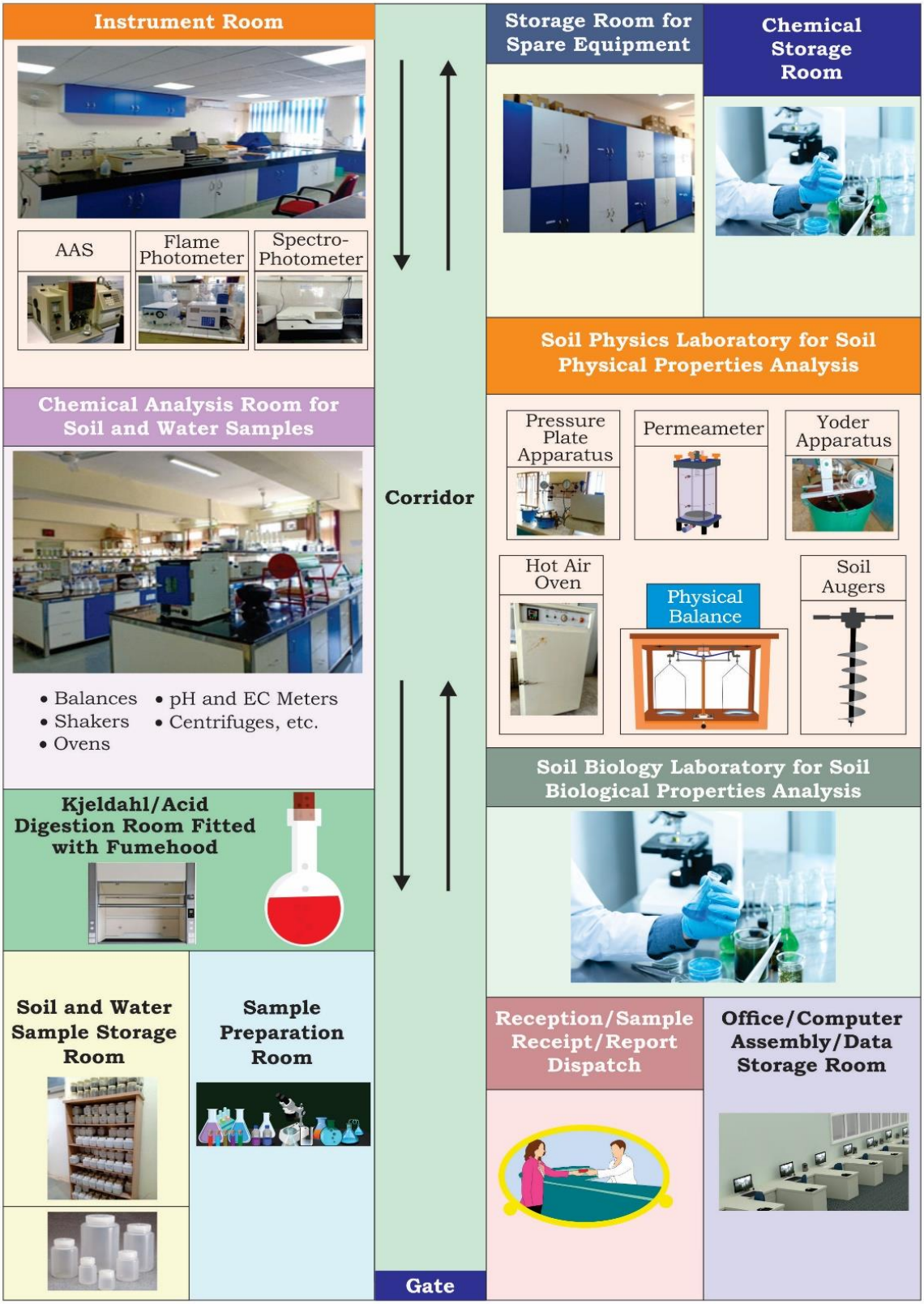


Fig.1.2: Floor plan of a soil, and water analysis laboratory

i. Sample processing room

The following steps are taken in the sample processing room:

- After arrival of samples at the laboratory, they are air-dried at room temperature (25-35°C) in a dust free, well-ventilated room by spreading out on a clean white paper or on a plastic sheet.
- Ensure that soil samples are not mixed with other soil samples. It may take about 1 to 2 weeks for the soil to sufficiently dry (3-4% moisture).
- After the sample has dried, it is passed using a 2 mm sieve to remove debris leaving behind fine soil (Figure 1.3).
- The fine soil sample is packed in well labeled plastic bags for analysis.

Fig.1.3: Sieving of soil samples

ii. Storage room

It is not always possible to analyze the received soil and water samples immediately. Therefore, proper storage of soil and water samples is essential before proceeding for analysis. The soil storage room is used for the storage of samples, both before and after analysis, with adequate shelf space. The samples are stored in cool and dry conditions with proper labels containing their IDs and data sheets. Information regarding name of farmer, location of the field, slope of the field, its drainage, previous history of cropping, quantities of fertilizer and manure applied etc. is contained in the data sheets.

a. Storage of soil samples

- The collected and already labeled soil samples are transferred to clean cloth or polythene bags.
- The labeling is done with thick paper tagged with sampling bags and marked with permanent marker for double confirmation of sample ID.

Fig.1.4: Soil sample storage
Fig.1.4: Racks

- These samples are then stored in sample storage racks (Figure 1.4).

Precautions taken while storing soil samples:

- Collected samples are kept in sample storage room to avoid contamination and protect from direct sunlight.
- Soil samples are kept at 4 °C for soil microbiological analysis.
- Fresh samples need to be taken for analysis of ammoniacal-nitrogen and nitrate-nitrogen content of soil samples.

b. Storage of water samples

- Collected water samples are stored in tightly capped clean glass or plastic bottles (Figure 1.5) after labeling sample ID, location and sample identification mark on the bottle
- In case of delay in testing of collected water samples, add 2-3 drops of toluene to prevent microbial growth and keep them in the refrigerator for future analysis.

Fig.1.5: Water sample bottles

iii. Freezer room

- Freezer room is essential for storage of soil, water samples and other important chemicals for biochemical analysis.
- The temperature of freezer ranges from less than 0 ^{0}C to -20^{0}C.
- Low temperature prevents growth of bacteria and other microbes that may spoil the soil and water samples.
- A person should wear appropriate clothing including gloves, goggles and shoes while entering a freezer room to prevent cold injuries.

***Fig.1.6:* Lab freezer**

Figure 1.6 shows a freezer which is used in the soil and water testing laboratory.

iv. Analysis room

In this room, the laboratory assistant/technician conducts all the different types of soil and water analyses. Good laboratory practices (GLPs) are required to be followed in this room. A well-equipped soil and water analysis room is shown in Figure 1.7. The GLPs have been already discussed in class XI textbook.

Fig.1.7: A well-equipped soil and water analysis room

The detailed list of glassware items (Figure1.8 a-z) and equipment (Figure 1.9 a-t) housed in analysis room.

S. No.	Glassware	Photographs
1.	**Volumetric flasks:** Used for making solutions, containing, collecting, and volumetrically measuring chemicals, samples, solutions, etc. for analysis. **Flask stand:** Used to keep the flasks in the laboratory.	*a* 
2.	**Funnel:** Used to pour liquids or fine-grained substances into containers with a small opening. **Funnel stand:** Used to keep, hold or store funnels safely and reliably during sedimentation.	*b* 
3.	**Beaker:** It is a large cylindrical vessel with a wide mouth which is used for stirring, mixing and heating liquids. **Beaker stand:** Used to keep the beakers in place.	*c* 

4. **Burette:** A graduated glassware used in quantitative analysis to measure volume of a liquid during titration. It has a graduated glass tube with a stopper at one of its ends.

   Burette stand/clamp: The burette is placed on a burette stand with a clamp to fix its position.

d

5. **Micropipette:** Used to transfer a measured volume of liquid precisely. A disposable polypropylene tip is attached to the micropipette to reduce the possibility of contamination.

e

6. **Test tubes:** Used to hold chemicals for storing, measuring and transferring them.

   Test tube stand: Used to hold the test tubes in an upright position.

f

7. **Multiple dispensing equipment:** Used for precise and repetitive dispensing of chemicals.

   Tilt Measure: Used to dispense measured quantities of concentrated acids. (2/5/10/20 ml volumes)

g

8. **Washing assembly:** Used for washing glassware and utensils used in the laboratory.

h

9. **Scoop:** Used for transferring solids to a weigh-paper for weighing, a watch glass or any other glassware like flasks, beakers etc.

Spatula and Micro-spatula: Used for scrapping, transferring, or applying powders and paste like chemicals or treatments.

Forceps/Tweezers: Used to grab small particles which cannot be grabbed by hands.

i

10. **Pestle and Mortar:** It is a set of two simple tools commonly used in laboratories for crushing and mixing of chemicals and salts. **It is made of glass, quartz or ceremic.**

j

11. **Sieves:** Used to separate soil particles on the basis of their size. Sieve number indicates number of openings per linear inch.

k

12. **Trays:** Multipurpose equipment used for a number of purposes like soaking, cleaning, autoclaving, storing, organizing, or carrying lab products and containing spills, as well as for staining samples.

l

13. **Fume hood:** A laboratory fume hood is a type of ventilation system that primarily functions to provide personnel protection against toxic fumes, vapours and dust. They also protect against chemical spills and fires by acting as a physical barrier.

m

14. **Hotplate:** A device with a flat surface and an internal electric heating element that is used for generating heat at a particular temperature.

n

15. **Reagent bottle:** Used to hold chemical liquids and solution for long-term storage**.**

o

16. **Squeeze bottle:** It is a bottle fitted with a nozzle and used to rinse various types of laboratory glassware such as test tubes and round bottom flasks.

p

17. **Storage bottle:** Used to store chemicals and prepared reagents.

q

18. **Lab goggles:** Provides protection from flying debris, chemical splashes, visible and near visible light and UV rays.

r

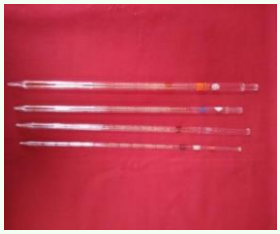
19. **Centrifuge tube with stand:** Used in centrifuge machines for separating solutes and solvents.

s

20. **Conical flasks:** Used for holding liquids and mixing them by swirling.

t

21. **Pipette:** Used to transfer an exact volume of liquid. Also used as a media dispenser.



u

22. **Measuring cylinders:** Used to measure approximate volume of liquids. Each marked line on the graduated cylinder measures the amount of liquid that has been put into it.

v

23. **Beakers:** A glass or plastic vessel cylindrical in shape which is used for holding liquids of approximate quantity.

w

24. **Petri dishes:** Used to culture different types of cells including bacteria and molds. It often contains a nutritional medium on which the cells can grow.

x

25. **Desiccators:** Sealable enclosures containing desiccants which are used for preserving moisture-sensitive items.

y

26. **Pipette stand:** Used to hold pipettes of different sizes.

z

Fig.1.8 (a-z): Essential glassware in analysis room

S. No.	Equipment	Photographs
i.	**Analytical balance:** Highly sensitive laboratory instrument designed to accurately measure accurately the weight of chemicals. It has a readability range between 0.1-0.01mg.	a 
ii.	**Electronic balance:** Equipment which is used to determine sample's weight in a laboratory.	b 
iii.	**pH Meter**: Instrument used to measure pH of the soil and water samples.	c 
iv.	**Electrical conductivity (EC) meter:** Instrument used to measure the soil salinity or electrical conductivity of soluble salt content.	d 

v.	**Spectrophotometer (UV and visible):** Instrument that measures the amount of light absorbed by a sample	*e* 
vi.	**Flame photometer:** Device used to determine the concentration of certain metal ions like sodium, potassium, lithium, and calcium.	*f* 
vii.	**Kjeldahl Assembly/Nitrogen distillation unit:** This unit comprises of different equipment assembled together as a unit, used for analyzing nitrogen in samples.	*g* 
viii.	**Mechanical shaker:** Used to mix, blend, or agitate substances in a tube or flask by shaking them in a horizontal or circular manner.	*h* 
ix.	**Magnetic stirrer:** Device which consists of a rotating magnet used for stirring or mixing a solution.	*i* 
x.	**Hot water-bath:** Equipment used to heat samples, it consists of a heating unit, a stainless-steel chamber that holds the water and samples, and a control interface. Moist heat is used to heat any substance to avoid direct heating.	*j* 

xi.	**Centrifuge**: Device that uses centrifugal force to separate different components of a sample.	*k* 
xii.	**Hot air oven:** Electrical device which makes use of dry heat to sterilize and heat.	*l* 
xiii.	**Atomic absorption spectrophotometer (AAS):** Device used to analyze materials like zinc, iron, manganese, copper etc., in a solution. Specially in soil test laboratory for estimation of micro, heavy and pollutant elements.	*m* 
xiv.	**Muffle furnace:** A device used for heating, enabling samples to be heat-treated at temperatures exceeding 500-1000 °C (1832°F) with low risk of cross-contamination.	*n* 
xv.	**Pressure plate apparatus:** Used for measuring soil moisture, under controlled conditions.	*o* 

xvi.	**Yoder apparatus:** Device used for the determination of wet aggregate stability in soil.	*p* 
xvii.	**Lab refrigerator:** These are used to cool the samples or specimens which are to be processed in future.	*q* 
xviii.	**Macro-Kjeldahl digestion block:** Used for the digestion and distillation process during the estimation of total Nitrogen.	*r* 
xix.	**Lab incubator:** Device used to maintain a stable environment for processes such as growing cells and microbiological cultures.	*s* 
xx.	**Water purification system:** This system helps in purifying water by eliminating undesired organic and inorganic chemical compounds.	*t* 

v. Instrument room

This room in the soil and water testing laboratory is equipped with simple instruments like pH meter, EC meter and advanced equipment like the Atomic Absorption Spectrophotometer etc. Figure 1.10 (a, b) shows a view of the instrument room at ICAR-IISS Bhopal.

The instrument room is air conditioned to keep the environment dust free as well as temperature controlled as per the requirement of most of the sophisticated instruments. Other important considerations are that the electric current is supplied from a 3-phase system, all instruments must have stabilizers to ensure constant power supply and the water supply on the laboratory should be continuous. Proper care is necessary to keep the workplace safe and free from accidents in the laboratory.

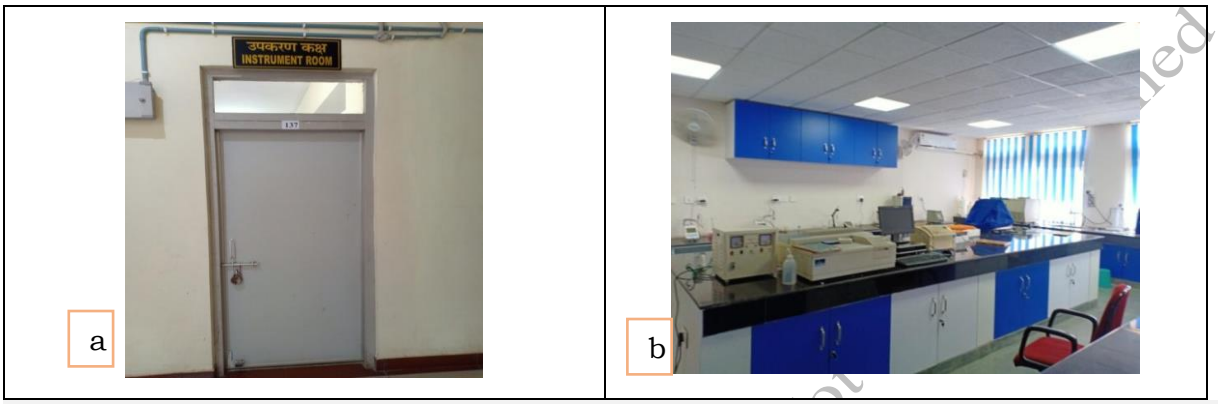


Fig.1.9 (a-t): Essential equipment in analysis room

Fig.1.10 (a, b): Instrument room at ICAR-Indian Institute of Soil Science, Bhopal

Appendix-I

Laboratory glassware (Glass and Plastics)

Items	Size/Specification
Bottle (polyethylene)	20 litres
Bottle (glass)	20 litres
Bottle (glass) for reagents with glass stoppers	Glass stoppered with various sizes (125 ml to 2000 ml)
Bottle (glass), amber	250 ml and 500 ml
Bottle (polyethylene) – wash bottle	250 ml and 500 ml
Burettes fitted with screw-thread stopcocks	
Graduation interval (ml)	
0.05	10 ml
0.05	25 ml

0.1	10 ml
0.1	25 ml
Burette (automatic) (mounted on reservoir) Graduation interval (ml)	
0.1	25 ml
0.1	50 ml
Cylinder (glass) graduated with an interval of:	
0.5 ml	10 ml
1 ml	25 ml
2 ml	50 ml
2 ml	100 ml
5 ml	500 ml
Crucible silica	30 ml
Desiccator (1,2 or 5 l)	
Water distilling unit, mounted with borosilicate condenser, with a capacity (output) to distil 2.5 litre/hour	
Flask distilling/Kjeldahl, round-bottom, long-neck	100 and 250 ml
Flask (conical)	100 and 250 ml
Flask (volumetric)	Of various capacities (ml) 25, 50, 100, 250, 500 and 1000 ml
Funnel, plain, (60-degree angle)	Of various diameters like 50, 65, 75 and 100
Volumetric/Graduated Pipette	Of different capacities (ml) like 1, 2, 5, 10, 25 and 50

Porcelain dish	100 and 150 ml
Test-tube	Of different capacities (ml) like 5, 10, 20, 25 etc.
Watch glass	As per the requirement
Rubber stopper	15, 18, 20, 25 and 30 mm diameter
Spatula (stainless steel) with wooden handle, blade length 100 mm	As per the requirement

Appendix-II

Methods for Estimation of Different Nutrients

Plant nutrients/forms	Estimation methods
Total Nitrogen (N)	Kjeldahl method
Mineralizable N	Alkaline $KMnO_4$ method
Nitrate-N (NO_3-N)	Phenol disulphonic acid method
Ammonium–N (NH_4-N)	Indophenol blue method
NH_4 and NO_3-N	Mineral nitrogen (2 M KCl method)
Available Phosphorus (P)	Bray's spectrometric method No. 1 for acid soils and Olsen's method for alkali soils
Available Potassium (K)	Flame photometric method (neutral ammonium acetate extraction)
Available Sulphur (S)	Spectrophotometric method barium sulphate precipitation method extraction with 0.15% Calcium chloride.
Calcium and Magnesium (Ca/Mg)	EDTA titration method
Zinc (Zn), Copper (Cu) Iron (Fe) and Manganese (Mn)	DTPA extraction and estimation by Atomic absorption Spectrophotometric method.
Boron (B)	Hot water extraction and estimation by AAS

	Hot water extraction and determination by azomethine H colorimetric method
Molybdenum (Mo)	Ammonium acetate extraction and estimation by AAS
	Ammonium oxalate extraction and estimation by colorimetric method

Activities

Visit a nearby soil and water testing laboratory and identify different rooms and equipment present in the laboratory as taught in the class.

Requirements: Soil and water testing laboratory, notebook, pen.

Step by step process:

- Go to the nearby laboratory with your teacher.
- Identify the different rooms and equipment present there.
- Make a note of it and discuss in the class amongst yourselves

Check Your Progress

Multiple Choice Questions

1. The main purpose of soil and water testing is
   a) Determine fertilizer requirement to optimize crop yield
   b) Determine crop quality
   c) Determine lime requirement
   d) All of the above
2. The soil and water testing laboratory is used for
   a) Providing extension advisory service to the farmers
   b) Develop report for fertilizer recommendation to different soil and crops
   c) Advise methods for improving soil health
   d) All of the above
3. The room used for soil sample processing should be
   a) Well ventilated
   b) Temperature of about 25°C – 35°C
   c) Both of the above
   d) None of the above

4. To prevent cold injuries in the freezer room the following aid is required

   a) Gloves

   b) Goggles

   c) Shoes

   d) All of the above

5. Main purpose of storage of soil sample in freezer room (<0 to -20°C) is

   a) Soil biochemical analysis

   b) Soil chemical analysis

   c) Both of the above

   d) None of the above

Fill in the Blanks

1. To remove stones/large pieces of debris soil is sieved through ..... sieve.
2. A true ..... sample is the one which represents the actual conditions of the study area.
3. Soil are kept at ..... °C for soil microbial analysis.
4. .....soil is used for chemical analysis of soil mineral (ammonical and nitrate) nitrogen.
5. Kjeldahl assembly is also called ..... distillation unit.

True or False

1. Instrument room should be dust free and air conditioned.
2. 2-3 drops of toluene is used to prevent microbial growth during the storage water samples.
3. Lab refrigerators are also useful in prepared standard solution and thermolabile chemicals for future use.
4. It is not mandatory to follow GLPs in the soil and water sample analysis room.
5. Micropipette is an essential item in analysis room.

Session 2: Collection and Processing of Soil and Water Samples

The method and procedure for obtaining soil samples vary according to the purpose of sampling. Soil and water analysis is needed for agricultural and engineering purposes.

In this session, we are going to learn about the different steps involved in soil and water testing such as collection methods: selection of site in the field,

collection of soil and water samples, processing of samples, their labeling and storage and sample registration and retrieving.

2.1 Collection of soil and water sample

As you already know by now, the purpose of soil testing is fertility evaluation and fertilizer recommendations for the given soil for the crop to be grown. Depending on the purpose of analysis, about 100 g of soil is used. Similarly, the water suitability is known through water analysis for different purposes like irrigation, domestic and drinking. About 400-500ml water sample is sent for analysis to the laboratory.

Do you know!

Weight of surface soil sample (0-15 cm depth) is about 2 million kg/ha. It is humanly impossible to analyze this much of soil. This can be achieved only by appropriate sampling techniques. Thus, proper sample collection is the first right step in this direction. Therefore, even systematic analysis may not give correct and representative results if sampling is faulty.

2.2 Purpose of soil testing

Intensive farming practices including high and injudicious application of fertilizers, pesticides and other inputs leads to nutrient imbalance, deterioration of soil health and declining crop productivity. Therefore, nutrient management of soils based on testing has emerged as an important approach for sustaining agricultural productivity and soil health. Following are the major purposes of soil testing:

- To ascertain the available nutrients status in soils.
- To study the type and extent of problem for reclaiming and ameliorating the problematic soils.
- Soil testing summarizes the fertility status as “High”, “Medium” or “Low” for the available nutrients.
- To evaluate and prepare the fertility map to describe the status of soils in a given state or a district.

Do you know!

The soil fertility map is used for –

Delineating areas of nutrient (e.g., N, P, K) sufficiency or deficiency and determining their requirements for the deficient areas.

Studying changing patterns of soil fertility due to crop cultivation over a period of years.

Recommend fertilizer, manures, ameliorant like lime and amendments like lime and gypsum.

i. *Sampling tools and accessories*

Depending upon the purpose and precision of soil sampling following tools may be needed:

- Soil auger- it may be a tube auger, post hole or screw type auger or even a spade for taking samples (Fig 1.11).
- A clean bucket, a tray, a clean cloth sheet or polythene sheet for mixing the soil samples.
- Cloth bags of specific size for sample collection.
- Observation notebook, pencil for marking and tags or aluminum labels for tying cloth bags.
- Soil sample information sheet (Fig. 1.14).

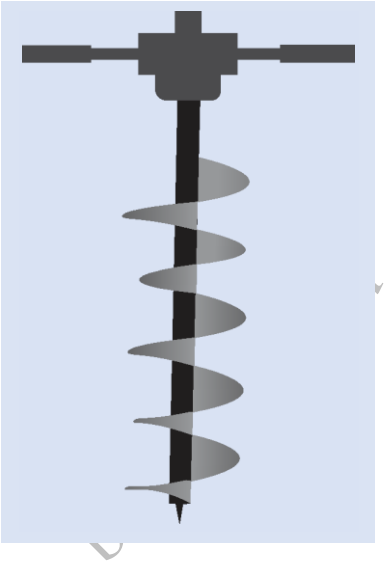


Fig.1.11: Soil auger

2.3 Selection of sampling locations

Intensive farming practices including high application of fertilizers, pesticides, ameliorants and other amendments. Figure 1.12 shows the different steps involved in the sampling process.

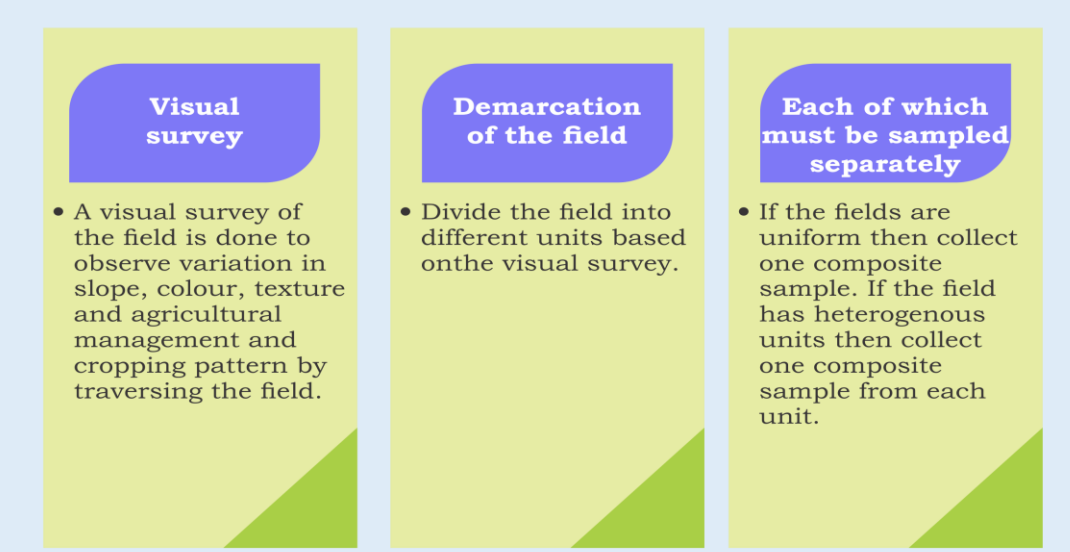


Fig. 1.12: Steps involved in sampling

2.4. Soil sample collection

An important step in obtaining accurate soil tests is collecting a representative sample in the field. The following steps are taken while collecting samples:

- Divide the field into small areas so that each sample represents an area of approximately 1 hectare.

- Uniform fields are sampled in a simple random pattern across the field.
- Prepare a map of the area to be covered showing different sampling unit boundaries by indicating different symbols or alphabets like A, B, C etc.
- Each area is traversed separately. A slice of the plough-layer is cut at intervals of 15 to 20 steps or according to the area to be covered.
- Use a spade or *khurpi or trench hole* for taking samples with a V-shaped hole to a plough depth of 15 cm. (Refer class XI textbook for detailed information). While sampling for fruit, cultivation soil from deeper layers 0-15, 15-30 cm should be collected.
- Cut 1.5 cm thick slice of soil from top to bottom of the exposed face of the V-shaped hole. (Figure 1.13)

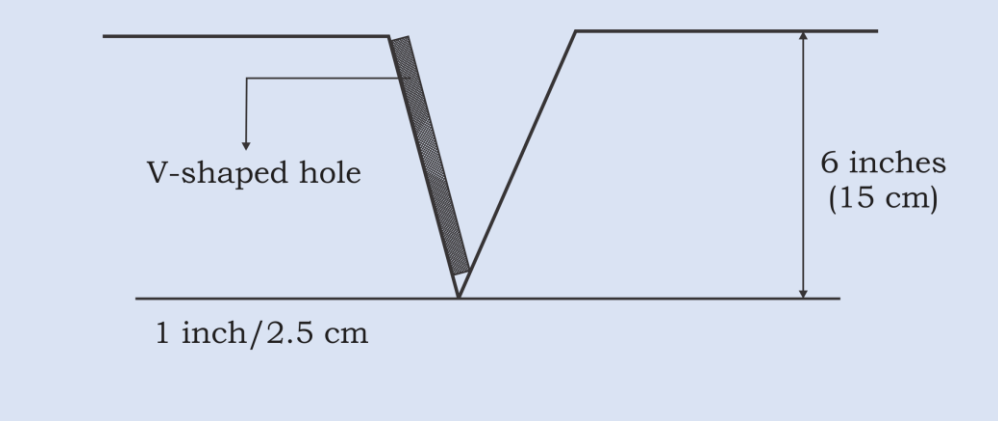


Fig. 1.13: V-Shape cut for soil sample collection

- Collect the soil in a clean bucket or tray or polythene sheet.
- Generally, 10 to 20 samples are taken to make one composite sample depending on the size of the field.
- Thoroughly mix the soil samples collected from these spots/fields.
- Put the soil from the bucket on a piece of clean paper or cloth and mix thoroughly.
- Spread the soil evenly on the piece of clean paper or cloth and divide it into 4 quarters.
- Reject two opposite quarters and mix the rest of the soil again.

- Collect only 500 to 1 kilogram soil samples and discard remaining samples by quartering process.
- Collect it and put in a clean cloth bag with proper labeling.
- Write the details about the samples in an information sheet.
- The format of soil sample information is given in Figure 1.14. Put a copy of this information sheet in the sample bag and ties the mouth of the bag carefully for transportation to the nearby soil testing laboratory.

Sample No.....

Name of the collector.....

Name of farmer..... Date.....

Farm size.....

Address..... Village.....
Post office..... Block.....
District..... State.....

Vegetation cover.....

Source of water .....

Water quality.....

Depth of sampling (cm).....

Previous crop.....

Slope or topography- level/sloping/ undulating

Elevation..... Upland/ lowland

Drainage..... Well drained/ moderate/ impeded

Irrigation..... Irrigated/unirrigated (rainfed)

Source of irrigation..... Well /tube well/ canal/ pond

Type of soil..... Sandy/loamy/ clayey

Special soil conditions..... Hardpan layer/rocky subsoil/

Cropping Details..... Crop variety Yield (kg/ha) Seed rate (kg/ha) For previous years 1. 2. For proposed years 1. 2.

Purpose of analysis:	Land capability assessment Fertility evaluation and fertilizer recommendation Salinity appraisal and causes of the source of salinity, if known Soil classification	Slope: 1–2 percent 2-5 percent 5-10 percent 10-25 percent > 25 percent
Irrigation method	Flood	Year of irrigation: Never irrigated
	Furrow	1-5
	Sprinkler	5-15
	Drip	
	Rainfed	
Years of cultivation	Never cultivated	Drainage: Good
	1-5	Moderate
	5-15	Poor
	>15	
Manure used in the previous crop and dose (t/ha) _____		
Fertilizers used in the previous crop and dose (t/ha) _____		

Fig 1.14: Example of a soil sample information sheet

- The bag used for sampling should be clean and free from any contaminants. The same bag can be used second time, if is turned inside out to remove the soil particles.
- The different steps involved in the soil sampling process

Quartering

"Quartering" is an important process in representative soil sample collection. In quartering, divide the mixed soil into four equal parts and discard two opposite parts. Then, remix the remaining two quarters and divide it into four parts. Reject two parts again and repeat this procedure until about 250-300 g of soil is left for collection.

i. *Time of sampling*

- Collect soil samples from the fields after harvest and before planting the next crop.
- Collect samples as close to the sowing season as possible to obtain for estimation of available nitrogen.
- Sampling in the fields is done at the same time each year or alternate years to get more consistent results.
- For available nutrients determinations, soil samples are collected in every two to three years.

ii. *Precautions in sample collection*

- Do not collect soil samples from unevenly fertilized land or immediately after fertilizer application, close to irrigation channel, field bunds, trees and site of previous compost piles in the field.
- For soft and moist soils, use tube auger or spade.
- For hard soil, use screw auger.
- For standing crops in the field, collect samples from the middle of the rows to avoid the area where fertilizer is applied.
- Avoid any type of contamination at all stages.
- Soil samples are never stored with fertilizer materials, detergents or any other chemicals.
- Information sheet should be clearly written with pencil/pen.

iii. *Sampling of salt affected soils*

To characterize the salt affected soils we need to collect both surface and sub-surface samples. Surface soil (0-15 cm) samples are collected in the same way as mentioned above. These collected samples are used to determine gypsum requirement of the soil. For reclaiming salt affected soils, it is important to know the properties of lower depth soils (sub-surface soils). Such soils are sampled to a depth of one meter using the soil auger.

Note: Information sheet of salt affected soil

The information sheet for salt affected soils contains the followings:

- *Soil hardness and permeability.*
- *Salinity cause and source, if known.*
- *Relief, seasonal rainfall, irrigation.*
- *Frequency of waterlogging, and water table depth.*
- *Soil management history, crop species and conditions of plant cover.*
- *Depth of the hard pan or concretion.*
- *Time of irrigation, amount of irrigation or rain received prior to sampling.*

2.5. Methods of water sample collection

Following procedure is followed while collecting water sample:

- Collect a representative water sample (500 ml) in glass or polyethylene bottle properly washed/rinsed with the same water (2-3 times).
- Avoid including the floating debris or any other contaminant while collecting the samples.
- Label the sample properly such as source of water, date of collection and the type of analysis required.
- Send the sample to the nearby laboratory as early as possible.
- In case of low concentration of anions such as SO_4^{2-} and NO_3^{3-} in irrigation water, collect 1-2 litres of sample.
- Evaporate the sample in a water bath (at 60-70^{0}C) to get about 100 ml to obtain their detectable amounts of these ions etc.

2.6. Dispatch of samples to the laboratory

Before sending soil or water samples to the testing laboratory, the following instructions are followed:

- Ensure proper identification marks (Sample ID) on the sample bags or containers.
- Place soil/water information sheets or labels in the bags.
- It is essential that sample ID/details are written by copying pencil or permanent marker. Avoid using ink pens while labeling.
- Compare the number and details on the bag with the dispatch list.

- Pack the samples properly in wooden/cardboard boxes/poly bags as they are most suitable for long transport.
- Pack soil sample bags in clean container for packing.

An organized receiving system is required in the soil and water testing laboratory to ensure prompt receipt of samples from different stakeholders like farmers etc.

2.7. Precautions taken after sample collection

- Do not leave samples in vehicles after collection. Samples are to be submitted to the laboratory as soon as possible.
- Store soil samples properly to protect them from contamination.
- Do not expose soil samples directly to the sun.
- Do not apply heat using hot air ovens or microwave oven. A fan may be used to speed up the drying process.
- Samples are air-dried by spreading out on clean white paper or plastic sheets under shade.

Why nitrogen analysis is done on the same day of sampling?

Soil samples collected for nitrate-N analysis are dried on the same day they are sampled. The samples are kept in the freezer/ refrigerator if drying is not possible on the same day. Failure to do so will result in higher nitrate readings due to mineralization of organic N (conversion of organic to inorganic form of nitrogen). This may result in less fertilizer N being recommended than is actually needed for a particular crop.

2.8. Processing of soil sample

After sample collection, different steps involved in processing of soil samples are described below:

i. Handling in the laboratory

- As soon as the samples are received at the soil testing laboratory, they are matched, and cross checked with its data information sheet.
- All unidentifiable samples are discarded.
- Information regarding samples is entered in a register and each sample is given a fresh laboratory number.

ii. Drying of samples

- Received fresh soil samples are air dried for 2 to 3 days under shade and open space in the laboratory.

- While drying, the trays are numbered or plastic tag is attached. The soils are then air dried.
- In general, excessive drying, such as oven drying of the soil, affects the availability of most of the nutrients present in the sample and should be avoided.

iii. Post drying care

- After drying, the samples are taken to the preparation room which is separated from the main laboratory.
- Plant materials (leaves and roots), pebbles, concretions and stones are removed before grinding.
- Air dried samples are ground with a wooden pestle and mortar so that the large soil particles are crushed into finer particles and passed through a 2 mm sieve.
- The coarse portions on the sieve are returned to the mortar for further grinding.
- Repeat the process of sieving and grinding till all aggregate particles are fine enough to pass through 2 mm sieve.

2.9. Labeling and storage of soil samples

- The soil samples are properly labelled with sample ID and stored in cardboard boxes in sample room.
- These boxes are numbered and arranged in an orderly manner in a soil sample room in a particular sequence (*e.g.,* a, b, c/ 1, 2, 3 etc.)

2.10 Sample registration and retrieving

- Along with each soil sample, sampling information sheet describes the location, cropping history, management practices followed and crops to be cultivated etc.
- Assign the sample analysis number and enter it in the laboratory register or computer aided records (data sheet).
- Field moisture content must be estimated in un-dried sample or to be preserved in a sealed polythene bag immediately after collection.
- Estimate the moisture content of sample before every analysis to express the results on dry weight basis.

Activities

Go to a field with your teacher and demonstrate how you will collect the soil samples with the help of an augar/spade/trench/hoe/spoon for sandy soil

Requirements: Selection of field, augar, carry bags, markers.

Step by step process:

- Go to a nearby field to collect soil samples.
- Demonstrate the process of soil sampling by making use of an augar or any other implement to your teacher as taught in the class.

Check Your Progress

Multiple Choice Questions

1. Which of the following is called soil sampling tool

   a) Soil auger

   b) Khurpi

   c) Spade

   d) All of the above

2. Screw auger is used for which soil

   a) Hard clay soil

   b) Sandy soil

   c) Waterlogged soil

   d) None of the above

3. Generally, the V-shaped cut (15 cm) for soil sampling is made in the soil with the help of

   a) Soil auger

   b) Spade

   c) Khurpi

   d) None

4. When quartering of soil is done for two rounds its volume is reduced by

   a) 1/2

   b) 1/4

   c) 1/8

   d) 1/10

5. The usual timing for soil sampling in the field is

   a) Before planting of crop

   b) After harvesting of the crop

   c) Both of the above

   d) None of the above

Fill in the Blanks

1. The testing of salt affected soil is done to determine the..... requirement of the soil
2. Water sample is collected in a polyethylene bottle after it is properly rinsed with ..... water repeatedly.
3. In case of low amount of anions or elements present in the water samples it is allowed to.....
4. The tag containing detailed information about the collected sample is called .....
5. The grinding of the big soil particles or clods is done by .....

True or False

1. Salt crust on surface soil is developed in acid soil.
2. Soil sample in storage should not be exposed to sunlight.
3. Fresh soil samples are generally dried at oven for chemical analysis.
4. Soil samples are properly labelled with sample ID for ease of its access and testing.
5. Too wet soil samples are not kept in the storage room.

Module 2
Instrument Calibration, Maintenance and Reagent Preparation

Module Overview

Most of the instruments and equipment used in soil and water testing laboratories manufactured by industries have their own calibration and factory settings. However, those calibrations may not be applicable for your purpose. Therefore, we need to calibrate the equipment using standard methods and procedures to get maximum accuracy in the analysis. In this Module we will learn about instrument calibration, maintenance and reagent preparation to get accurate results.

Learning Outcomes

After completing this module, you will be able to:

- Explain the procedures for preparing primary and secondary standard solutions, including accurate measurement, dilution techniques, and ensuring solution stability.
- Describe the methods for calibrating and maintaining instruments in a soil and water testing laboratory, ensuring accuracy, reliability, and longevity of equipment such as pH meters, spectrophotometers, and titrators.

Module Structure

- Session 1: Preparation of Primary and Secondary Standard Solutions
- Session 2: Calibration and Maintenance of Instruments in Soil and Water Testing Laboratory

Session 1: Preparation of Primary and Secondary Standard Solutions

1.1 What is a solution?

A solution is defined as a homogenous mixture of two or more substances. One of the simple examples of a solution is sugar or salt dissolved in water.

Sugar solution = Solute (sugar) + Solvent (water) (Figure 2.1)

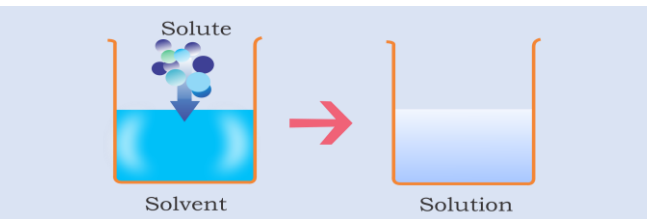


Fig. 2.1: Formation of a solution

1.2 Reagents

A reagent is a substance or compound added to a system to start a chemical reaction, or to detect the presence or absence of another substance. For example: Sodium hydroxide (NaOH), Hydrochloric acid (HCl) which are used to detect the presence of acids and bases, whereas reagents like Fehling's reagent, Millon's reagent, Tollens' reagent, Acrolein reagents are used to detect biochemical compounds such as carbohydrates, proteins and fats respectively. Some of the commonly used reagents in soil and water testing laboratory are Potassium di-chromate ($K_2Cr_2O_7$), Ferrous ammonium sulphate [$Fe(NH_4)_2SO_4$], Ammonium acetate (CH_3COONH_4), Sodium bi carbonate ($NaHCO_3$), Sulphuric acid (H_2SO_4), Nitric acid (HNO_3), Hydrochloric acid(HCl)etc.

1.2.1 Primary standards

A primary standard is a reagent that is highly pure, stable with a formula that does not change when exposed to atmosphere and has high molecular weight. Primary standards are used to calibrate other reagents. These calibrated reagents are referred to as working standards.

For example:

1. Sodium carbonate (Na_2CO_3) is used as a primary standard which is used for the standardization of hydrochloric acid (HCl).
2. Suppose we need to prepare a series of concentrations of a reagent like NaCl with varying strengths i.e., 0, 5, 10, 20, 50 and 100 ppm (parts per million). For this first we need to take 100 mg (0.1 g) NaCl in 1 liter of distilled water which will give 100ppm of NaCl solution. This is known as the stock solution or standard solution. Now from this if we take 5 ml of solution and add water to make 100 ml this will give a 5ppm solution. Similarly, 10 ml gives 10 ppm solution and so on.
3. In analytical chemistry, the primary standard is used for calibration of secondary standard.

Characteristics features of a primary standard include:

- High grade of purity (> 99.98%).
- They are extremely stable (low reactivity).
- Low hygroscopicity (anhydrous form and no weight changes due to relative humidity).
- High equivalent weight (negligible weighing errors).
- Ready to use and easily available.
- Preferably non-toxic (less harmful form).

Examples of primary standards for titration of solutions:

These are materials which, after drying under the specified condition, are recommended for use as primary standards in the standardization of unknown solution.

Examples of primary standards used:

1. **Acid-base titrations:** Potassium hydrogen phthalate ($C_8H_5KO_4$), Anhydrous sodium carbonate (Na_2CO_3).
2. **Redox- titrations:** Arsenic trioxide (As_2O_3), Sodium oxalate ($Na_2C_2O_4$), Potassium bromate ($KBrO_3$), Potassium dichromate ($K_2Cr_2O_7$) etc.
3. **Precipitation titrations:** Sodium chloride (NaCl).

Table 1 shows the different types of titrations.

Table 1. Types of Titrations

Types of titration	Examples of secondary standard
1. Acid base titration	• Hydrochloric acid (HCl) • Sulphuric acid (H_2SO_4) • Sodium hydroxide (NaOH) • Perchloric acid ($HClO_4$)
2. Redox titration	• Potassium permanganate ($KMnO_4$) • Ceric ammonium sulphate [Ce $(NH_4)_2(SO_4)_2$. $2H_2O$] • Sodium thiosulphate ($Na_2S_2O_3 \cdot 5H_2O$)
3. Precipitation titration	• Ammonium thiocyanate (NH_4SCN) • Potassium thiocyanate (KSCN) • Mercuric nitrate [Hg $(NO_3)_2$]
4. Complexometric titration	• Sodium salts of EDTA [$C_{10}H_{14}N_2Na_2O_8$] • Lead nitrate [Pb $(NO_3)_2$]

The uses of primary standards are depicted in the following figure 2.3.

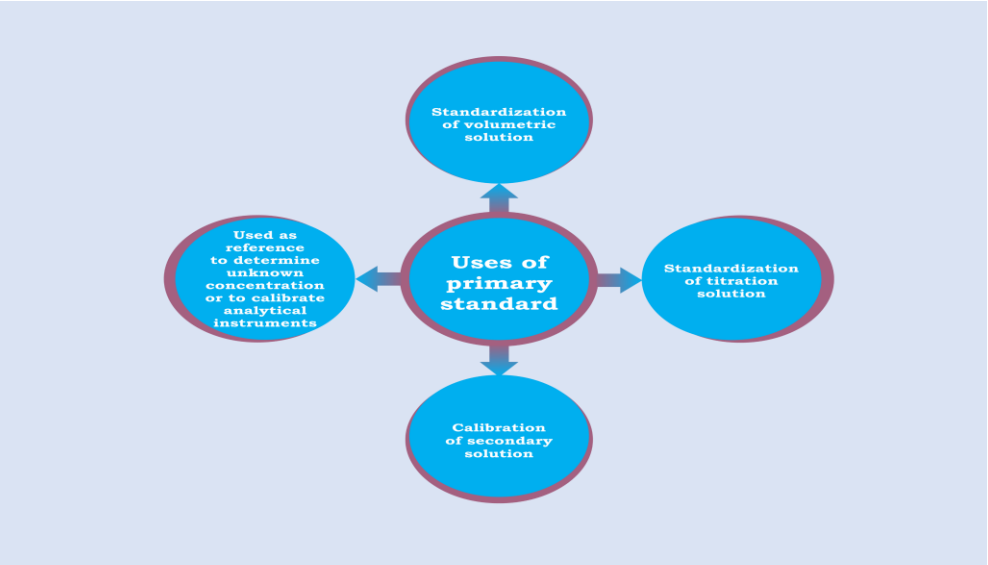


Fig. 2.3: Uses of primary standards

Volumetric solutions are the solutions of reagents of known concentrations, primarily used in quantitative determination where as a titrant is the solution added to react with the analyte (whose concentration is being determined).

1.2.2 Secondary standards

Secondary standard is a chemical that has been standardized against a primary standard which is used in specific analysis in soil and water testing laboratory. A secondary standard is a chemical or reagent which has certain properties such as:

- It has less purity than primary standard.
- Less stable and more reactive than primary standard.
- Its solution remains stable for a long time.
- Titrated against primary standard.

The uses of secondary standards are depicted in the following Figure 2.4.

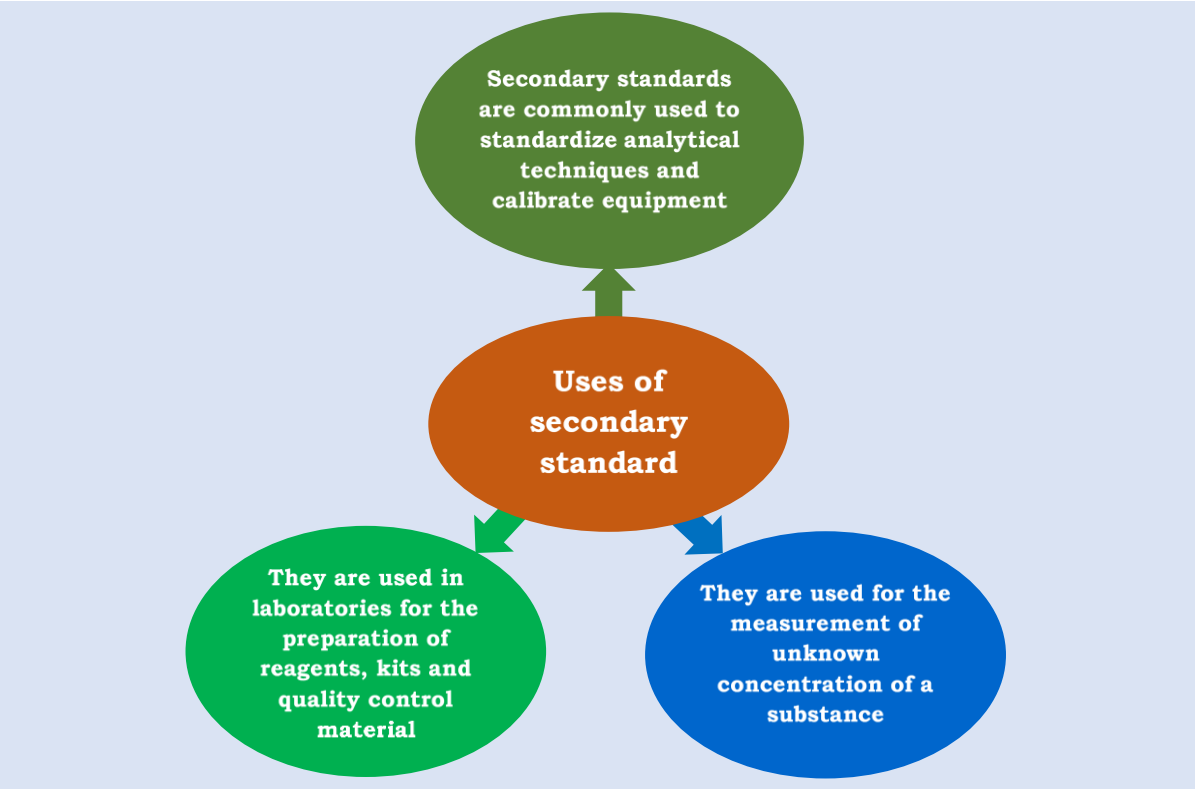


Fig. 2.4: Uses of secondary standards

Uses of secondary standards

1. Secondary standards are commonly used to standardize analytical techniques and calibrate equipment.
2. It is used for the measurement of unknown concentration of a substance.
3. It is used in laboratories for the preparation of reagents, kits and quality control material.

Table 2 shows differences between primary and secondary standards.

Table 2. Difference Between Primary and Secondary Standards

Properties	Primary standards	Secondary standards
Solution	Made out of primary standards	Made out of secondary standards
Purity	Solutions are extremely pure (about 99.9%)	Solutions are relatively less pure than primary standard

Reactivity	Less or non-reactive	Relatively more reactive
Hygroscopicity or water absorption	Primary standards are not hygroscopic.	Secondary standards may be hygroscopic
Uses	To standardize secondary standards and other reagents	Used for the preparation of reagents, kits etc.

Do you know!

Auto-oxidizing agent: *Potassium permanganate ($KMnO_4$) is a secondary standard and a good oxidizing agent. Due to its reactivity, it itself gets oxidized to form manganese oxide (MnO_2) which may contaminate its chemical composition.*

Hygroscopic chemicals: *Some of the chemicals absorb moisture from the atmosphere and become moist and are known as hygroscopic. Example: Sodium hydroxide (NaOH). As soon as the bottle containing NaOH is opened, it starts absorbing moisture from atmosphere and within no time it becomes moist or hydrated. This you can test yourself in the laboratory as described in the activity below.*

Try it yourself:

Take the NaOH bottle near an analytical balance.

Place a Petri dish and make its weight as zero (by using the tare button).

Now open the container and place little NaOH flakes or pellets on it and quickly note the weight.

Now keep the glass windows of the analytical balance open for few minutes.

Observations:

Notice the gradual increase in its weight in terms of milligrams (mg) units. This is because NaOH flakes or pellets absorb water molecule from air.

1.3 Standard solution

Standard solution means a solution which contains a known concentration or weight of an element or reagent or substance in a definite volume of a solution. A standard solution is prepared by dissolving an accurately weighed quantity of highly pure substance in a definite volume of solvent. Concentration of solution can be expressed in different ways namely normality (N), morality (M), molality (m), percentage (%), parts per million (ppm), parts per billion (ppb) etc.

For example: To make 1% NaCl standard solution, take 1g of NaCl in a 100ml volumetric flask and make up volume to 100 ml mark. This creates a 1% NaCl

standard solution. Accurate weighing is a very important step in preparing different concentration (strength) of solutions e.g. : 1 g means exactly 1.000 g and not 1.008 g or 1.080 g etc. (Figure 2.5).

Fig. 2.5: Preparation of 1% NaCl standard solution.

Purposes of standard solutions in titration: Figure 2.6 shows the different purposes of standard solutions in titration reaction.

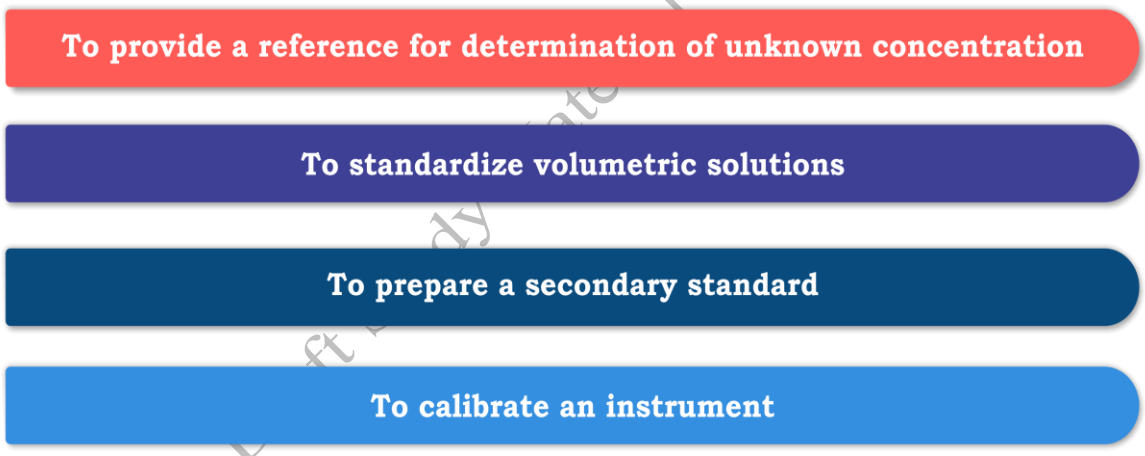


Fig. 2.6: Purposes of standard solutions in titration

Types of standard solutions: There are two types of standard solution as described:

1.3.1 Primary and secondary standard solutions

Reagents and standard solutions are the core of analytical chemistry. The accuracy, repeatability and precision of chemical analysis of soil and water quality depend upon the accuracy of the reagents and standard solution.

An accurate known mass of a primary standard is dissolved in a suitable solvent in a definite volume is called '*primary standard solution*'. Similarly,

a known volume of secondary standards preparation in a definite volume is called '*secondary standard solutions*.

- In analytical chemistry, primary and secondary standard solutions are used for volumetric (quantitative) analysis.
- These are used to determine the concentrations of other substances, such as solutions in a titration.

Fun fact

Vinegar, a common flavoring agent used in industries as well as in cooking, is an aqueous solution of acetic acid and trace chemicals that acts as flavoring agent which typically contains 5-8% acetic acid by volume.

Difference between accuracy and precision in measurements

Accuracy: *Accuracy refers to how closely the measured value of a quantity corresponds to its "true" value.*

Precision: *Precision expresses the degree of reproducibility or repeatability in an analysis/experiment/study. For better precision, a greater number of measurements are required which will minimize the errors.*

Basic terminology in soil and water analysis

1. **Molecular weight:** Molecular weight is a measure of the sum of the atomic weight of all the atoms in a molecule.
   - It is unitless, may be expressed in terms of atomic mass unit (amu) or Daltons (Da).
   - The terms molecular mass, molecular weight, and molar mass are often used interchangeably. For example, the molecular weight of water (H_2O), which has two atoms of hydrogen and one atom of oxygen, is 18 (i.e., 2 + 16).
2. **Molar mass:** It is defined as the mass in g of 1 mole of the substance. It is generally expressed in g/mol. A mole of any substance includes 6.022×10^{23} molecules (i.e., **Avogadro's Number**)

   Mathematically, the defining equation of molar mass is:

Molar mass = mass/mole = g/mol

What is Avogadro's Number?

It is the number (6.022×10^{23}), named after the Italian scientist Amedeo Avogadro, that is constituent particles of one molecules, atoms or ions of any substance.

Solved example 1: Calculate the molar mass of 100 g of NaCl (molecular mass of Na is 23 g and Cl is 35.5 g)

Solution: Molecular mass of NaCl is = 23+35.5 = 58.5 g

therefore, in 1 mole of NaCl = 58.5 g

So, in 100 g NaCl, the molar mass = 100/58.5 = 1.709 g

Solved example 2: Molecular weight or molar mass calculation of methane (CH_4) gas.

	Standard atomic weight	Number of atoms	Total molar mass (g/mol) or molecular weight (Da or g/mol)
C	12.011	1	12.011
H	1.008	4	4.032
CH_4			16.043

In the similar way you can calculate the molar mass of any molecule.

Do you know!

Atomic mass and the molar mass of carbon-12 are numerically equal. They differ only in units; atomic mass is measured in atomic mass units, and molar mass is measured in grams per mole.

The mass of one mole of carbon-12 atoms is exactly 12 grams; its molar mass is exactly 12 grams per mole

3. **Equivalent weight:** It is also known as gram equivalent, is the mass of one equivalent of a given substance which will combine with or displace a fixed quantity of another substance.

Different aspects of equivalent weights

- It is measured by the atomic or molecular weight of a compound divided by its valency.

Valency: *It is the ability of an atom to gain or lose electrons in order to achieve the noble gas [Helium (He), Neon (Ne), Argon (Ar), Krypton (Kr), Xenon (Xe) and Radon (Rn)] electronic configuration.*

- with or displaces 1.008 gram of hydrogen or 8.0 grams of oxygen or 35.5 grams of chlorine.
- These values correspond to the atomic weight divided by the usual valence; for oxygen as example that is 16.0 g / 2 = 8.0 g.
- For acid-base reactions, the equivalent weight of an acid or base is the mass which supplies or reacts with one mole of hydrogen cations (H^+) or one mole of hydroxyl anions (OH^-).
- For redox reactions, the equivalent weight of each reactant supplies or reacts with one mole of electrons (e^-) in a redox reaction.
- The equivalent weight of a compound can be calculated by dividing the molecular mass by the number of positive or negative electrical charges that result from the dissolution of the compound.

4. **Molarity (M):** It is defined as the number of moles (n) of solute/analyte in a litre (L) of solution.
   - Molarity is used to calculate the volume of the solvent or the amount of the solute.
   - The molarity of any given solution is a method for knowing the specific elements or compounds.

$$\textbf{Molarity (M)} = \frac{\textbf{n}}{\textbf{V}}$$

Where, n = number of moles of the solute,

V= volume of the solution

Solved example 1: Calculate the molarity of solution prepared by mixing 2.0 g of NaCl in 500 ml of water

Calculation:

2.0 g NaCl (1 mole of NaCl is58.5 g NaCl) = 2/58.5 = 0.0342 moles of NaCl

Now, 500 ml water = 0.5 L of solution

Then, M= n/V= 0.0342/0.5 =0.0684 mol/L

Do you know!

Similar to molarity (M), the molality (m) is defined as the number of moles of solute per kilogram of solvent.

5. **Normality (N)**: It is defined as the number of 1 g equivalent weight of solute per litre of solution.
    - Common units of normality include N, eq/L, or meq/L.
    - Normality is a measure of concentration equal to the gram equivalent weight per litre of solution.
    - Gram equivalent weight is the measure of the reactive capacity of a molecule.
6. **Mole fraction:** The mole fraction or molar fraction is defined as unit of the amount of a constituent (expressed in moles), divided by the total amount of all constituents in a mixture (also expressed in moles). This expression is given below:

$$\text{Mole Fraction (m)} = \frac{\text{Unit amount of mole of a constituent}}{\text{Total number of moles of all constituents (moles/moles)}}$$

    - The sum of all the mole fractions is equal to 1.
    - The same concept expressed with a denominator of 100 is the mole percent, molar percentage or molar proportion (mol %).
    - Mole fraction is a ratio of moles to moles whereas molar concentration is a quotient of moles to volume.
7. **Percentage (%):** It is a number or ratio expressed as a fraction of 100,
    - A percentage is a dimensionless number (pure number).
    - It has no unit of measurement.

    Solved example: 4 g of NaOH dissolved in 100 ml of distilled water gives 4/100 * 100 = 4 % NaOH solution.
8. **Parts per million (ppm):** It is a way of expressing very dilute concentrations of substances and expressed as milligrams per litre or parts per million (mg/L or ppm).

> ***Do you know!***
>
> *ppm=mg/liter =µg/ml*
>
> *1 ppm =1000 ppb*

Solved example: A solution containing 10 mg of KCl/ litre of solute is 10 ppm KCl solution. Similarly, 10 micrograms of KCl per millilitre of solution is 10 ppm KCl solution.

How to convert percentage to ppm and vice-versa

The percent (%) may be converted to parts per million (ppm) by multiplying with a factor 10,000 or 10^4. In order to express the results as a percent, divide the nutrient content (which is expressed in ppm) by 10,000.

For example: If the reported value for P_2O_5 is 2,690 ppm, the calculation to convert to percent would be:

2,690 ppm ÷ 10,000
= 0.269%.

Composition by weight (w) and volume (v) is a measurement of the concentration of a solution is represented as w/v (%)

To calculate w/v (%) concentration:

$$\text{W/V (\%)} = \frac{\text{Mass of solute (g)}}{\text{Volume of solution (mL)}} \times 100$$

- Common units for w/v % concentration is g/100 mL (%).
- Solubilities are sometimes given in units of grams of solute per 100 mL of water, i.e., as a weight/volume percentage concentration
- Note: weight/volume is a useful concentration measure when dispensing reagents.

9.1 Percentage composition by weight: The concentration is expressed in terms of the gram of solute per 100 g of solution.

e.g., 10% KCl solution is prepared by dissolved 10 g of the salt in 90 g of water.

9.2 Percentage composition by volume: The concentration is expressed in terms of volume of the solute and solvent.

e.g. 25 g of solution of methanol is prepared by mixing 25 ml of methanol with 80 ml of water. [Density =mass/volume; density of methanol is 0.7918 g per 1 ml]

Table 3: Preparation of Commonly Used Standards in Soil and Water Testing Laboratory

To prepare 1000 ml (1 litre) of 0.1N solution (approximately) of secondary standards	To standardize with primary standards [A.R. grade]
Sodium hydroxide (NaOH) 4.0 g to be dissolved in water and make up the volume to 1 litre (L).	**Potassium hydrogen phthalate (0.1 N)** Dissolve accurately 5.105 g of potassium hydrogen phthalate in water and make up the volume to 250 ml.
Potassium hydroxide (KOH) Dissolve 5.7 to 6.0 g of KOH in water and make the volume up to 1litre.	**Succinic acid (0.1N)** Weigh 5.9 g of succinic acid to be dissolved in water to make up the volume to 1 litre.
Silver nitrate ($AgNO_3$) Dissolve accurately 16.989 g crystallized (A.R.) $AgNO_3$in water & make up the volume to 1 litre.	**Sodium chloride (0.1N)** Weigh 5.486 g of sodium chloride and dissolve in water to make up the volume to 1 litre.
Sulphuric acid (H_2SO_4) Dilute 2.8 ml of conc. 36N H_2SO_4 to 1L (36N x? ml = 0.1 N x 1000) = 2.8 ml OR considering the gram equivalent wt., purity and Specific Gravity of the H_2SO_4, dilute calculated amount of H_2SO_4 in distilled water and make up to 1litre.	**Sodium carbonate (0.1N)** For this weigh exactly 5.29 g of dry sodium carbonate and dissolve in water and make the volume up to 1 litre.
Hydrochloric acid (HCl) Dilute 8.33 ml of conc. 12.0 N HCl to 1 litre of distilled water. (12N x x ml = 0.1 N x 1000) = 8.33 ml	
Nitric acid (HNO_3)	

Dilute 6.3 ml of conc. 16N nitric acid to 1 litre of distilled water.	

Activities

Prepare a 1 litre of 1 N NaOH solution in your laboratory.

Requirements: NaOH, Volumetric flask and distilled water.

Step by step process:

1. Weigh 40 g of NaOH.
2. Dissolve this in 1 litre of water (1000ml) in a volumetric flask.
3. This will give 1N solution of NaOH.

Similarly, you can prepare 1000 ml of 2N solution by dissolving 80 g of NaOH.

Check Your Progress

Multiple Choice Questions

1. Examples of primary standards used for redox titration is
   a) Arsenic trioxide (As_2O_3)
   b) Sodium oxalate ($Na_2C_2O_4$)
   c) Potassium dichromate ($K_2Cr_2O_7$)
   d) All of the above
2. Standard prepared from sodium hydroxide is
   a) Primary standard
   b) Secondary standard
   c) Both of the above
   d) None
3. The molecular weight of water (H_2O)
   a) 14
   b) 16
   c) 18
   d) 20
4. The sum of all the mole fractions is equal to
   a) 1
   b) 100
   c) 1000

d) None

5. 0.1 N of NaOH solution contains

a) 0.4 g of NaOH /litre

b) 4 g of NaOH /litre

c) 40 g of NaOH /litre

d) None of the above

Fill in the Blanks

1. Calibration is the process of configuring an instrument to provide a precise result for a sample within an …… range.
2. Solution = ……+ Solvent.
3. A reagent is a substance or compound added to a system to start a …… reaction.
4. Sodium carbonate (Na_2CO_3) is used as a …… standard.
5. The mass of two mole of carbon atoms is exactly …… grams.

True or False

1. Primary standards have low grade of purity and extremely unstable.
2. H_2SO_4 is called as primary standard.
3. 1%=100 ppm.
4. A highly precise sample has lower degree of reproducibility or repeatability in an analysis.
5. Molarity is defined as the number of moles (n) of analyte in a litre (L) of solution

Session 2: Calibration and Maintenance of Instruments in Soil and Water Testing Laboratory

2.1 Calibrate and maintain instruments for analysis

Calibration and maintenance are crucial steps in the proper functioning of any laboratory instruments/equipment. In this process, we detect any deviation in the instrument accuracy and eliminate them by correlating and adjusting with reference to standard with known accuracy.

2.1.1. Calibration and maintenance of instruments in soil and water testing laboratory

Calibration and maintenance are meant for effective and accurate working of laboratory instruments/equipment. We ensure that an instrument

reading is accurate with established standards and reference materials through calibration. The calibration is needed under certain circumstances as shown in the Figure 2.7

The calibration procedures vary with the instrument types and their models. In this session, we will learn about the method of calibration and maintenance of standard laboratory instruments.

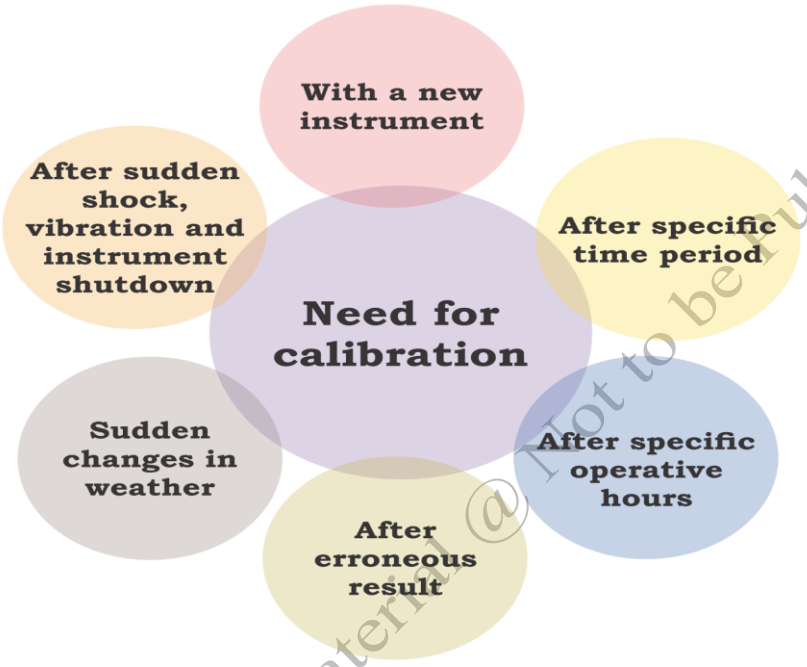


Fig.2.7: Need for instrument calibration

Daily calibration is often required for better performance of weighing balance.

***a. Pre-requisite of calibration procedure*:**

- Weighing balance should be placed at a horizontal platform. It may be checked through the attached spirit level or bubble level.
- Record the technical characteristics of the instruments such as maximum weight, value of scale division (d-value), accuracy requirement (maximum error allowed and uncertainty), steps to be followed if the calibration fails (adjustment).
- Ensure for enough "standard weights" for the calibration procedure is available.
- Weighing instruments should be switched on at least 20-30 minutes before the start the calibration process.
- The instrument and standard weight kept at same working environments (preferably at 25 ^{0}C).

b. Calibration procedure:

- Switch ON the main electrical power supply and instrument power button.
- Wait till zero reading is displayed on the screen.
- Allow the instrument to get stabilized for 15-20 seconds and select the weight for calibration (preferably in milligram or gram).
- Place the standard weight on the platform. The display should be the same or within one least count, as per weight place.
- Record the observations during instrument calibration record book.
- If the display reading does not match with the standard weight or permissible limit, put an "out of order" label and get it rectified by the service engineer.
- Do not use the balance till it is rectified/repaired.

Note: Always use a standard weight which is certified by weights and measure department.

2. pH meter

The pH meter measures the acidity or alkalinity of soil and water samples. The pH meter may be calibrated before every use to ensure accuracy and precision.

a. Prerequisite of calibration procedure:

- pH meter should be placed at room temperature of 25 ^{0}C.
- Prepare the buffers of different pH (4.0, 7.0 and 9.2) with the buffer tablet or readily available solution. Always use more than one buffer for calibration.

Buffers: These are the standard solution with known pH value which are used to calibrate the pH meter in a laboratory.

- Instrument must be switch on mode for 15-20 minutes for warm-up
- Place the probe of the pH meter into a standard buffer solution.
- Compare the instrument reading with the known pH of the buffer solution. Simultaneously measure the pH of the distilled water (pH=7.0) to know whether the instrument is working properly or not.

- If the known pH value is not matched with the instrument reading and fluctuates, then the calibration procedure is followed.

b. Steps for calibration of pH meter

- In a combined pH-EC meter, ensure the meter is in pH mode with the room temperature on display.
- Before calibration, rinse the probe thoroughly with deionized water and wipe it with clean and dry paper towels/tissue paper.
- For a 3-point calibration, use high pH (9.2), pH (7.0) and low pH (4.0) solution. Pour your buffers into individual beakers for calibration.
- First measure the pH of "neutral" buffer (pH of 7.0), use the calibrate button to match the pH meter reading exactly with the buffer pH value.
- Then measure the second buffer solution's pH either of pH 4.0 or 9.2 and use the calibrate button again.
- Similarly, measure the pH for the third buffer solution.
- Stir the probe very gently to create a homogenous sample during every measurement.
- Data will be automatically saved after each calibration point.
- Buffers with a higher pH (9.2) are best for measuring basic or alkaline samples, whereas buffers with a low pH (4.0) are best for measuring acidic samples.
- Once you have chosen your buffers, allow them to reach the same temperature (preferably at 25 ^{0}C) as the pH meter readings are temperature dependent.
- Discard the buffer when the calibration is done.

c. Maintenance of pH meter

- The most sensitive and delicate component of pH meter is the glass electrode. The thin-walled glass bulb is often broken due to rough handling.
- It may dry up when kept out from deionized water for a longer period.
- If dried, the electrode should be immersed first in 0.01 N HCl and then in distilled water for one or two days and check again for its sensitivity.

3. Electrical conductivity (EC) meter

- The EC meter is used to measure the salt concentration in soil and water samples.
- The change in temperature influences the rate of salt dissolution in the solution.
- The measurement unit of EC is mhos cm^{-1} or ds m^{-1}.

a. Prerequisite of calibration procedure:

- Ensure that you have deionized water to rinse the conductivity probe.
- Different calibration standards are necessary for the various ranges of the conductivity test.
- A thermometer is needed if your meter does not record the temperature of the solution.
- Finally, ensure the EC meter is set to calibration mode before you begin calibrating.

b. Steps for calibration procedure

- Start by rinsing the probe with deionized water. Then, insert it into a calibration standard poured into a plastic cup. Sometimes use of metal cup may disrupt the EC meter.
- Calibrate EC meter with the standard of known EC. Note that unit display in EC meter and calibration packet should be same.
- Give EC probe a minute to settle into the solution and allow the solution to interact with the probe.
- Measure the solution temperature with a thermometer.
- If the EC meter reading does not match with a calibration standard, adjust the meter using “calibrate" button.
- After calibrating your probe, rinse it with deionized water and then place it in the sample to be tested.
- Ensure you don't introduce any bubbles into the solution, as it may disrupt the conductivity reading.
- When testing multiple samples, ensure to rinse the probe between each sample sufficiently.
- Some EC probes come with a special storage solution; thus, the probe kept inserted into this solution until the next use.

c. Maintenance of EC meter

- When the EC meter is not in use, place the probe in deionized water.
- Keep the cells perfectly clean for accurate readings.
- Rinse the cell with deionized water during measurement.
- For cleaning the electrode, take it out of its storage solution and rinse it with deionized water.
- Once rinsed, dry it with clean and soft tissue paper.
- Avoid rubbing the electrode as it has a sensitive membrane around it.
- If the electrode looks dirty, follow the operating manual for recommended cleaning solutions.

4. UV-visible spectrophotometer

- This instrument is used to measure the concentration of a substance by measuring the amount the light absorbed by the samples at UV (200-400 nm) and visible (400-700 nm) wavelength ranges (Figure 2.9).
- The measurement of concentration of any substances is carried out with respect of known concentrations or standard solution.
- In principle, it is a colorimetric (measurement of colours) analysis based on the measurement of radiant energy or absorption spectra after it passes through a sample solution.

The output of a UV-VIS spectrophotometer is called as absorption spectra as shown in Figure 2.8.

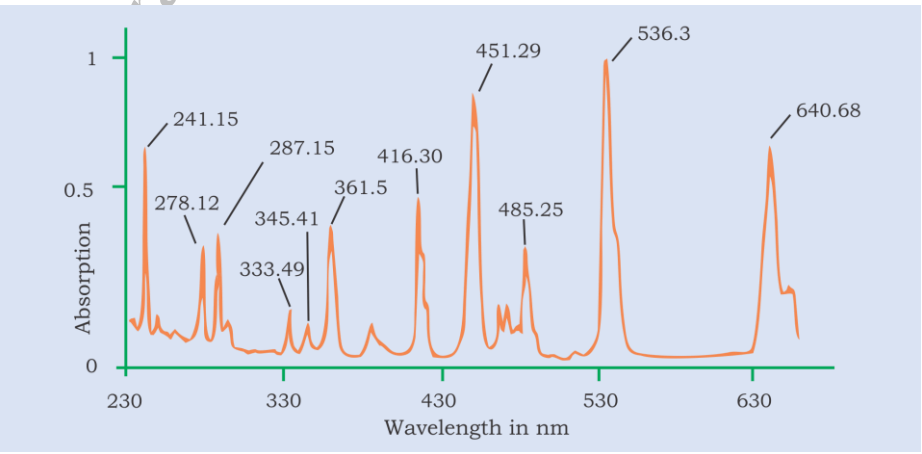


Fig. 2.8: Absorption spectra obtained in UV-VIS Spectrophotometer

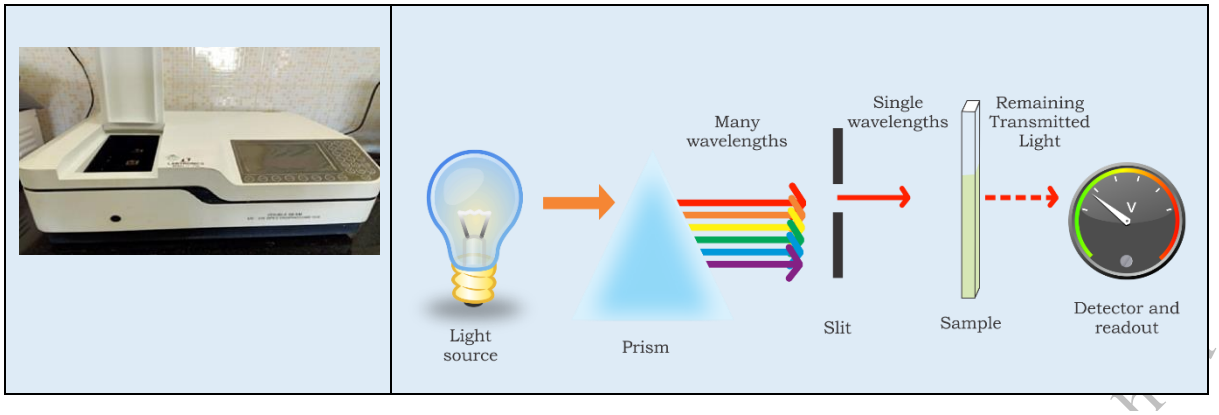


Fig. 2.9: UV -Visible Spectrophotometer

a. Prerequisite of calibration procedure:

- A series of standards is required for the target substance or reagent at lower concentration up to 10 ppm to develop a calibration curve.
- Ensure the availability of deionized water and working standards for washing of the cuvette and soft tissues.

b. Procedure of calibration:

Calibration of the UV spectrophotometer involves the following steps-

- Wavelength calibration
- Absorbance calibration
- Stray right control
- Resolution power

i. Wavelength calibration:

- Weigh accurately 1.0 g of holmium oxide (4% w/v) and dissolve it 1.4M perchloric acid ($HClO_4$) solution and make up the volume with 25 ml with the same solvent.
- Select the method file of control of wavelength in the instrument.
- After selecting the file press reference button for baseline correction.
- Then fill the cuvette with 1.4 M perchloric acid and put in the sample cubicle and press reference to zero.
- After auto zero put the holmium perchlorate solution in sample cubicle then press the start key.
- Scan and verify the wavelength using absorption maxima of holmium perchlorate solution.

- The permitted tolerance limits are followed while using UV-visible spectrophotometer (Deviation should not be greater than ± 1 nm in the ultra-violet and ± 3nm in the visible range).

ii. Absorbance calibration

Dry some quantity of potassium dichromate (K_2CrO_7) by heating to constant weight at 130 ^{0}C on a hot-plate.

a) Weigh 57 to 63 mg of potassium dichromate (primary standard) and transfer to 1000 ml volumetric flask. Dissolve in 0.005 M sulphuric acid and make up to the mark with the same acid.

b) Measure the absorbance at different wavelength namely 235 nm, 257 nm, 313 nm and 350 nm using 0.005 M sulphuric acid as reference material.

c) For visible region: Whole procedure is same as UV region but at the end measure the absorbance at 430 nm.

Calculation: value of A (1%, 1 cm)

$$\textbf{A (1\%, 1 cm)} = \frac{\textbf{Absorbance}}{\textbf{Weight (gm)}} \times \textbf{100}$$

iii. Stray light control: Stray light is defined as the detected light of any wavelength that is outside the bandwidth of the wavelength selected.

- The causes for stray light are scattering, higher order diffraction of the monochromator, or poor instrument design.
- Stray light causes a decrease in absorbance and reduces the linear range of the instrument.
- It severely affects high-absorbance measurements.
- It causes a deviation from linearity at high absorbance.

For the stray light test, various cut-off filters or solutions are used to estimate its contribution, depending on the wavelengths is used.

Scan the stray light testing solution in a 1 cm cell using air as the reference.

a. Prepare a solution of 1.2% (v/v) potassium chloride and dissolve with 50 ml distilled water.

b. Determine the absorbance using path length of 1 cm at 200 nm against purified water as blank.

Acceptance criteria: Absorbance at 200 nm should be greater than 2.0.

iv. Resolution power

a. Prepare a solution 0.02% (v/v) toluene in hexane
b. Record the spectrum of 0.02% (v/v) toluene in hexane from 250-300 nm using hexane as a reference material.
c. Record the absorbance at 269 nm (max) and 266 nm (min) using hexane as blank solution.
d. Calculate the ratio of absorbance by dividing the absorbance at maxima and minima.

Acceptance criteria: Absorbance ratio at 269 nm to 266 nm is not less than 1.5

Steps for calibration of spectrophotometer

It is a process by which the scientists or lab technicians uses a calibration standard to find out the light sources accuracy. It is vital to make sure that the device functions properly and the correct measurement is obtained. However, the calibration technique varies depending upon the make and brand of instrument.

A fundamental part of analysis is establishing an accurate calibration curve for quantitative analysis. This process involves

- A series of known solutions to be analyzed, including a "blank" prepared to contain no measurable amounts of the substances or elements of interest.
- Blank solution is designated as "zero" concentration and, together with one or more known standards, comprises the calibration curve.
- Samples are then analyzed and compared to the mathematical calculation of signal vs. concentration established by the calibration standards (Figure 2.10).
- Unfortunately, preparation of contamination-free blanks and diluents (especially when analyzing for many elements), perfectly accurate standards, and accurate laboratory measurements are always challenging task.

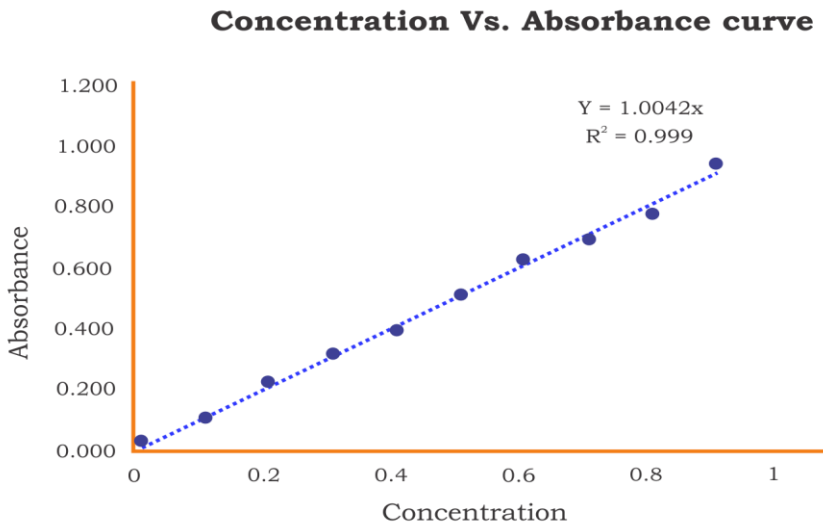


Fig. 2.10: Calibration curve with concentration of standard and absorbance reading of the instrument

Maintenance

- Ensure that instrument is protected from mechanical shocks and vibration at the surface.
- Clean the instrument case and sample compartment regularly with tissue paper or soft cloth slightly dampened with water or cleaning solution. Disconnect the power cord during cleaning the instrument.
- Do not open the sample compartment during instrument initialization and ensure it is ready for operation.
- Always clean the cuvette and hold in rough surface before placing it in sample holder and ensure it is free from dust in order to avoid scratches.
- Always measure the concentration from lower concentration to higher order and wash the cuvette with the same solution before its transferring sample holder.
- Consult in competent engineer in case of any fault in the instrument
- Proper power back up with automatic voltage stabilizer with AC current supply is required for optimum function of the instrument.

5. Flame photometer

Flame photometer works by measuring the intensity of light emitted when the element is exposed to a flame. The flame photometer is used to measure different elements such as potassium (K), sodium (Na), lithium (Li), calcium (Ca), magnesium (Mg) and barium (Ba).

The following steps are needed to calibrate the flame photometer.

a. Prerequisite of calibration procedure:

Given standard solutions depending on the element to be tested, working standard to be prepared for calibration process.

b. Steps for calibration

- Prepare a series of standard solution as per elements in increasing concentration (e.g., 0, 5, 10, 15, 20 and 25 ppm).
- Aspirate or feed the standards in increasing concentration into the flame photometer and note down the readings
- Plot a calibration curve of intensity vs concentration.
- Aspirate the unknown solution and record the display reading (intensity).
- Read the sample concentration from the calibration curve.

c. Maintenance

- The instrument should be always free from dust.
- Place the instrument away from any strong magnetic or electric field or any electric apparatus generating high frequency.
- Avoid the direct sunlight.
- To extend the life of source lamp, powered it only when required.
- The temperature of all solution used in the test should not differ by more than 0.5 ^{0}C.

2.2 Atomic Absorption Spectrophotometer (AAS)

Atomic absorption spectrophotometer is used for measurement of large number of trace element or micronutrients (Fe, Cu, Mn and Zn) and heavy metals (Cd, Pb, Cr, Hg and As). Usually, calibration of AAS is done once a month or as per the conditions.

a. Prerequisite of calibration procedure:

- Preparation of standard solutions depending on the element to be tested, series of working standards for calibration process.
- Ensure that the necessary standards are available as per the elements of interest.
- If samples contain multiple heavy metals then multiple reference standards of various elements are required to be prepared.
- Standards should be prepared in sufficient amount with double distilled water to avoid interference during absorbance.

b. Calibration process:

The following steps are taken during the calibration process.

1. Operate the instrument as per the standard operating procedures on the instruction manual.
2. Use specific standards of interest. For example, if you have to calibrate for copper estimation, then prepare series of standards for copper (1-5 ppm of Cu).
3. The series of standards differs from element to element. For example: for Fe the series of standards vary from 5 to 25 ppm.
4. Aspirate the sample or solution and measure the absorbance.
5. Calculate the correlation coefficient (r). The r value should be around 0.999, then the instrument is calibrated.

c. Calibration Curve:

Prepare standard solutions of at least 3-5 different concentrations (e.g., 1, 2, 3, 4 and 5 ppm), measure the absorbance of these standard solutions, and prepare a calibration curve from the obtained values.

Then measure the absorbance of the test solution and its concentration in a measurable range and determine the amount of concentration of the object element from the calibration curve.

d. Maintenance of AAS:

- Use standard operating procedure and user's manual for proper handling and operation of the instrument. For switching on the instrument, first stop the gas supply and burner.
- Keep the standard and samples free from any suspended materials by filtering through Whatman No.42 filter paper to prevent clogging of the instrument nebulization assembly.
- Do not directly feed the instruments highly strong acid and salt solution.
- Maintain a continuous flow of air-gas mixture to the burner.
- Do not leave the flame completely unattended.

Activities

Visit a nearby soil and water testing laboratory and identify different rooms and equipment present in the laboratory as taught in the class.

Requirements: Soil and water testing laboratory, Notebook, Pen

Step by step process:

- Go to the nearby laboratory with your teacher.
- Identify the different rooms and equipment present there with their utility.
- Make a note of it and discuss in the class amongst yourselves.

Try to handle the instruments with precautions in presence of demonstrators.

Check Your Progress

Multiple Choice Questions

1. The measurement unit of EC is mhos cm^{-1} or ds m^{-1}.

   a) mhos cm^{-1}

   b) ds m^{-1}

   c) Both of the above

   d) None

2. Different pH Buffers used for pH meter calibration are.

   a) pH 4.0

   b) pH 7.0

   c) pH 9.2

   d) All of the above

3. Buffers are the standard solution with ..... pH value which are used to calibrate the pH meter in a laboratory.

   a) known

   b) unknown

   c) low

   d) None

4. A temperature record of the solution is not required for the calibration of EC meter.

   a) EC meter

   b) pH meter

   c) All of the above

   d) None

5. A instrument need calibration when it gives erroneous results.

a) Erroneous results

b) After specific time period

c) Sudden change in weather condition

d) All of the above

Fill in the Blanks

1. A pure distilled water has the pH value of .....
2. EC meter is not in use, place the probe in ..... water.
3. Calibration and maintenance are meant for effective and ..... working of laboratory instruments.
4. ..... electrode is very sensitive and delicate components of pH meter.
5. In UV-visible spectrophotometer wavelength varies from ---------- to.....

True or False

1. Flame photometer is used for the analysis of Na and K.
2. Weight of samples may change in very cold and hot environment.
3. The calibration procedures do not vary with the instrument types and their models.
4. Weighing balance should be placed in horizontal position without any surrounding vibration.
5. Multiple standards is required for the calibration of AAS for analysis of more than one heavy metals.

Module 3
Soil Health Card and Interpretation

Module Overview

It is important to assess the soil fertility status from time to time to help the farmers to maintain good soil health and crop productivity. The soil health card scheme has played a significant role in this. In this unit we will study the different aspects of soil health, their importance, soil health card and its interpretation.

We shall also learn about the method of soil health card preparation, its interpretation, and fertilizer recommendation based on the soil test report.

Learning Outcomes

After completing this module, you will be able to:

- Explain the concept of soil health, including its key indicators, importance for sustainable agriculture, and methods for assessing soil physical, chemical, and biological properties.
- Describe the process for preparing a soil health card, including data collection, interpretation of soil test results, and providing recommendations for soil management practices to improve and maintain soil health.

Module Structure

- Session 1: Concept of Soil Health
- Session 2: Preparation of Soil Health Card

Session 1: Concept of Soil Health

Soils are essential for all terrestrial living entities, including human beings. Soil provides approximately 78% of the food consumed by humans that directly comes from crops. Another 20% of food comes from other sources that rely indirectly on the soil. This indicates that soil is critical for the survival of humanity. It is said that "soil is dynamic natural material that the civilization is built on". Although different functions are performed by the soil systems there are five essential soil functions which are most important.

These functions are accomplished by one or several specific soil properties, called the ‘soil health indicator’ (Figure 3.2).

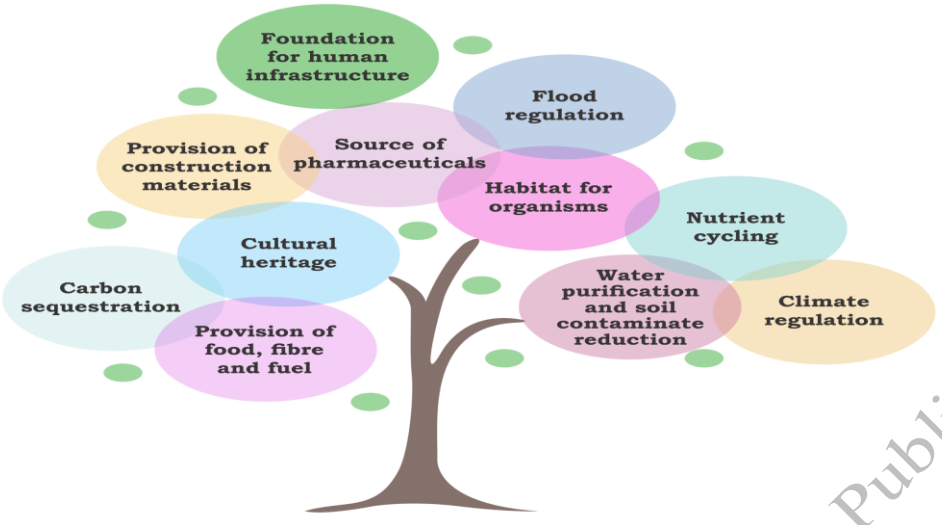


Fig. 3.2: Soil health indicators

Figure 3.3 shows the relationship between different soil functions and soil properties.

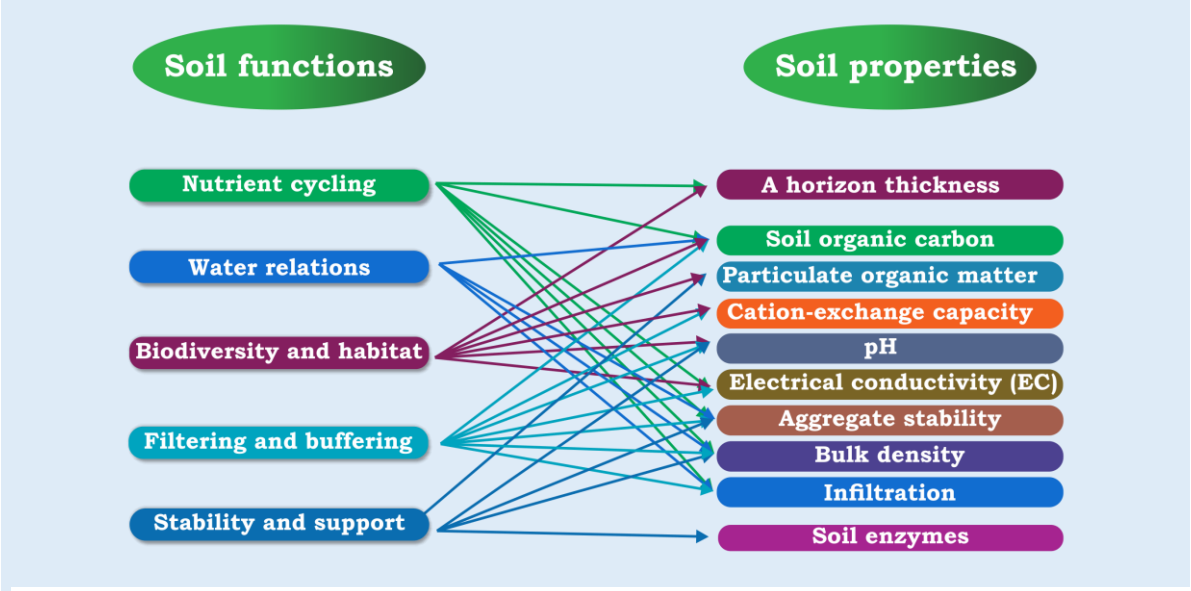


Fig. 3.3: Relationship between soil functions and soil properties.

Soil health

Soil health is defined as "The *capacity of a soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and promote plant and animal health*".

Soil health is thus the manifestation of its physical, chemical and biological component, as shown in Figure 3.4.

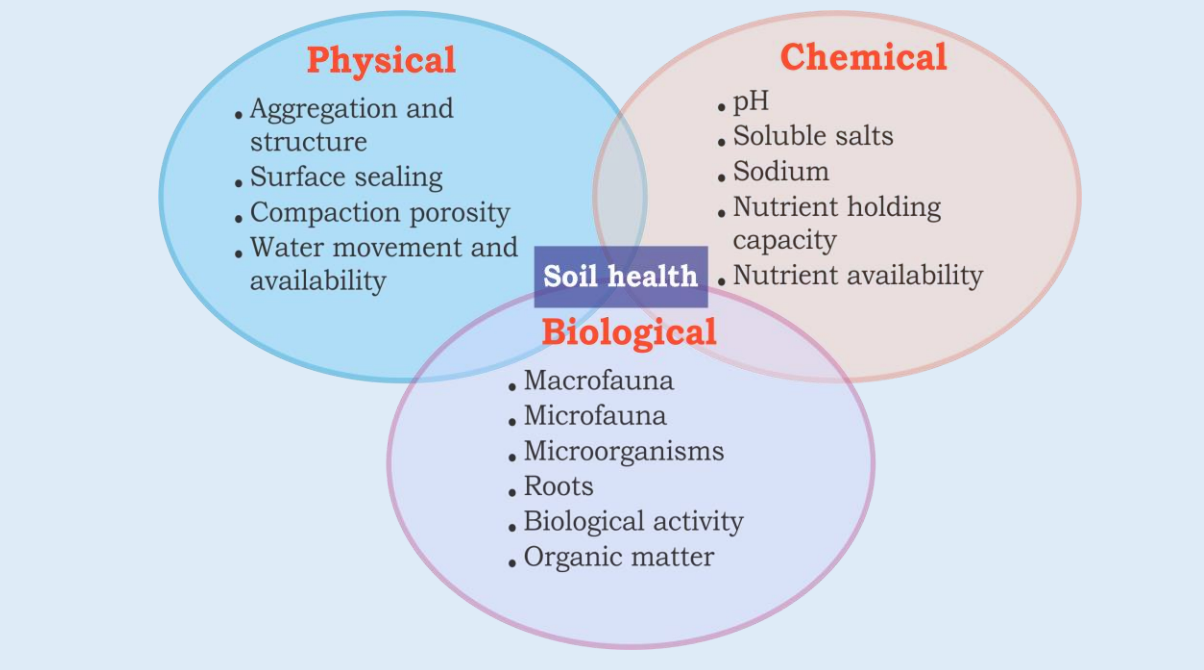


Fig. 3.4: Interaction of physical, chemical and biological components of soil

It is important to understand that interaction among these components creates and sustains a healthy soil in a particular location and time. The soil physical, chemical, and biological properties work cohesively, neglecting one aspect of soil health will affect other aspects.

1.1 Soil health indicators

In India, about 60% of the total population depends on agriculture for their livelihood. Declining soil productivity is a matter of serious concern. Soil is a vital resource for achieving food, nutritional, environmental and livelihood security. Therefore, managing and conserving soil resource is vital for future generations.

Soil health indicators provide information about how well the soil functions to achieve the management goals. Since, a specific soil function may involve several processes, and each process is linked with combination of soil chemical, physical, and biological properties. Therefore, the exact number of properties measured to assess soil health may vary according to the management goals. This is because a single property does not describe soil health. Soil health includes a combination of various properties such as soil organic carbon, texture, water holding capacity, essential nutrients, etc.

Soil health indicators consist of the criteria as shown in Figure 3.5:

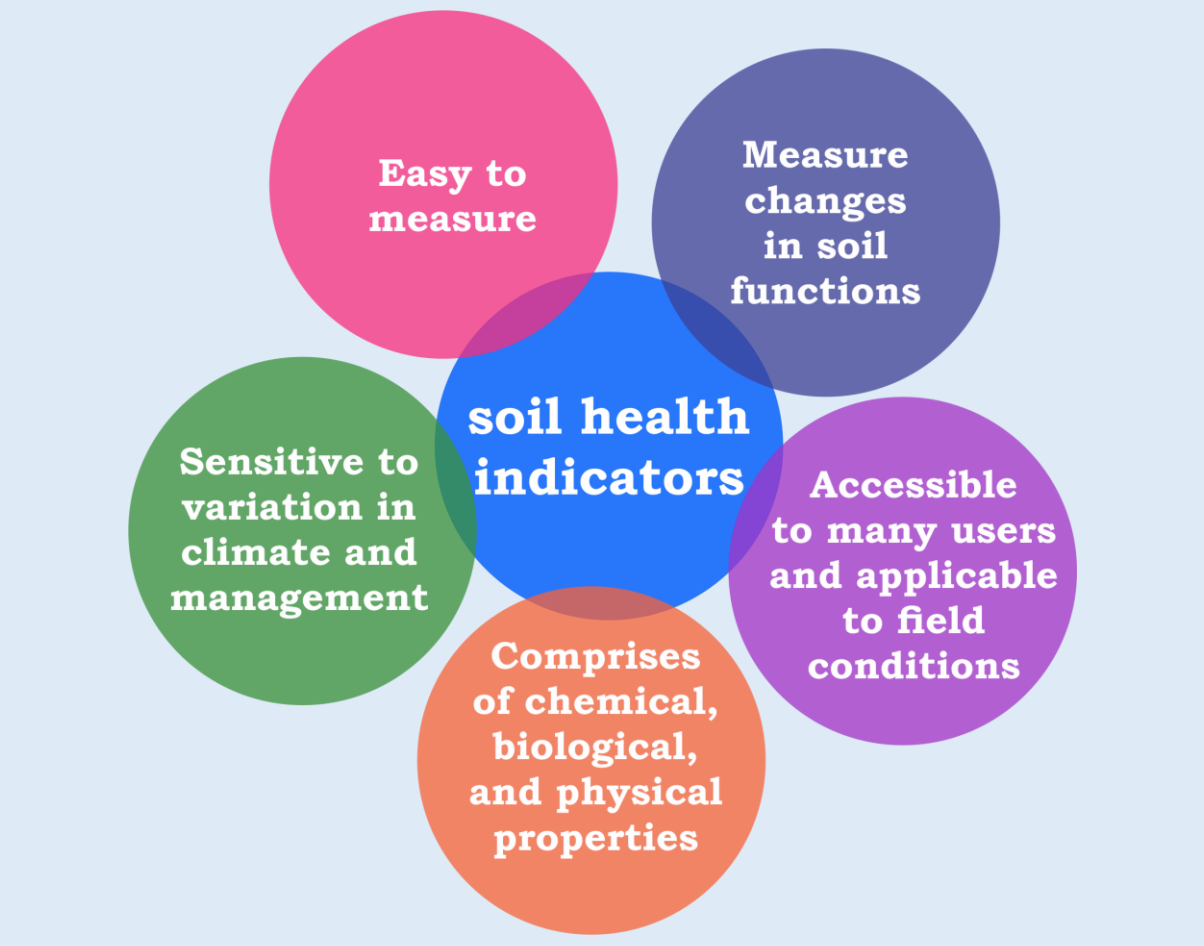


Fig. 3.5: Criteria of a good soil health indicator

A Soil Health Card is used to assess the current status of soil health to determine changes in soil health that are affected by land management over a period of time. A Soil Health Card displays soil health. The indicators included in the soil health card are typically based on farmers' practical experience and knowledge of local natural resources. The card lists a total of 12 soil health indicators as described below:

1.1.1 Soil pH

Soil pH is the measurement of soil acidity and soil alkalinity. It affects soil and plant health by affecting other soil properties. The best soil pH range for crop growth is close to neutral pH (pH 6 to 7.5), although some crops prefer to grow in acidic or alkaline soils. In acid soils, calcium (Ca) and magnesium (Mg), nitrogen (N), phosphorus (P), boron (B), and molybdenum (Mo) are generally deficient, whereas aluminium (Al), iron (Fe)and manganese (Mn) are abundant and sometimes reach toxic levels for some plants. On the other hand, P, Fe, Cu, Zn, and B are usually deficient in alkaline soils. The microbial population will decline at low pH levels, whereas fungi adapt to a large pH range (acidic and alkaline) most microorganisms prefer optimum pH range for their growth.

1.1.2 Soil EC

Soil EC is the measure of the amount of salts in soils. Some amount of salts are always present in the soil. When the concentration of salts in soil is below the critical limits, it doesn't affect plant growth. But with increasing salt content in the soil, plant growth and productivity will adversely affect. It also affects crop suitability, plant nutrient availability, and soil microorganisms' activity, which influences key soil processes, including greenhouse gas emissions (GHGs) such as nitrogen oxides, methane, and carbon dioxide.

1.1.3 Soil organic carbon

Soil organic carbon (SOC) is the most important indicator of soil health. The importance of SOC in food production, mitigating climate change and achieving sustainable development goals is well known. The SOC is added into the soil by plant and animal residue decomposition, root exudates, soil biota and living and dead microorganisms. A high soil organic matter (SOM) content improves water availability, soil fertility and ultimately improves crop productivity. The SOC also improves soil structure and porosity, ensuring sufficient aeration and water infiltration to support plant growth.

1.1.4 Macro and secondary nutrients

The macro and secondary nutrients are vital to plant growth. In soil health card, available N, P, K (primary nutrients) and S (secondary nutrient) are included. These nutrients are also part of 17 essential nutrients required for plant growth. The variation of these nutrients' availability significantly changes the crop yield. Therefore, correction of their deficiencies is often required through commercial fertilizers.

1.1.5 Micronutrients

In soil health card, Zn, Fe, Cu, Mn, and B are included as soil health indicators. The plant requires these nutrients in relatively smaller quantities than macro and secondary nutrients. However, micronutrients are as critical as other essential elements for plant growth. If micronutrients are limited, the enzymatic and hormonal activities inside plants are affected, resulting in reduced crop growth and ultimately the yield and quality.

1.2 Soil health card mission

Indian soils witness a negative nutrient balance of about 12-14 million tons per year. This negative nutrient balance is likely to further increase over time due to intensive agriculture practices and population pressure. The nutrient deficiency in Indian soil is reported in the order as shown in the following table.

Nutrient	Deficiency (%)
Nitrogen (N)	95
Phosphorus (P)	94
Potassium (K)	48
Sulphur (S)	25
Zinc (Zn)	41
Boron (B)	20
Iron (Fe)	14
Manganese (Mn)	8
Copper (Cu)	6

The deficiency of any single nutrient limits other nutrients functionality, deteriorates soil health and lowers fertilizer response and crop productivity. Presently, nutrient use efficiency (NUE) is low in our country and ranges from 30-50% for N, 15-20% for P, 60-70% for K, 8-10% for S and 1-2% for micronutrients. Therefore, improving NUE is more meaningful rather than applying more fertilizers.

To address such imbalances the SHC is employed so that judicious use of chemical fertilizers, N, P, K and secondary and micronutrients in conjunction with organic manures and bio-fertilizers can be done to improve overall soil health and productivity.

It also focuses on strengthening soil and fertilizer testing facilities to provide soil test-based recommendations to farmers to improve soil fertility. Under this programme, training is also offered to upgrade the skill and knowledge of soil testing laboratory staff, extension workers and farmers.

1.3 Soil health card scheme

Keeping in view of soil health's importance, the Government of India (GoI) has launched the Soil Health Card (SHC) Scheme on 19 February 2015. Since then, 19 February has been known as '*Soil Health Card Day'* to celebrate the birthday of the "King of Thailand" Under the scheme, the GoI issues soil health cards to farmers with crop-wise recommendations of nutrients and fertilizers required for the individual farms.

The salient features of the SHC scheme are:

- It covers maximum farmers across the country.
- The farmers will get a SHC report containing all the details about their farm.
- A farm will get the soil health card once in every two years.

Some facts about SHC scheme

SHC scheme was launched during 2015 to evaluate soil fertility of every farm holdings across the country in every two years. During cycle –I (2015-17), 10.74 crore Soil Health Cards and during cycle – II (2017-19), 11.74 crore Soil Health Cards have been distributed to farmers.

The SHC provides two sets of fertilizer recommendations for six crops including recommendations of organic manures.

Farmers can also get recommendations for additional crops on demand. They can also print their card from SHC portal. The SHC portal has farmers database of both the cycles and is available in 21 languages for the benefit of the farmers.

The National Productivity Council (NPC) found that implementation of SHC scheme decreased the use of chemical fertilizer in the range of 8-10% and increased in the crop yields to the tune of 5-6%.

Do You Know!

The United Nations declared 2015 as the International Year of Soils with the aim of increasing awareness and understanding of the importance of soil for food security and essential ecosystem functions.

World Soil Day (WSD) is held annually on 5 December to focus attention on the importance of healthy soil and sustainable management of soil resources.

The Food and Agriculture Organization (FAO), through its website on World Soil Day is encouraging different stakeholders like governments, organizations, communities and individuals on a global scale for improvement of soil health.

Activities

Go to a farmer's house who has a Soil Health Card. Interpret the information given in it as per the lesson taught in the class.

Requirements: Soil Health Card.

Step by step process:

1. Go to a farmer's house.
2. Observe the Soil Health Card.

3. Interpret the Soil Health Card as per the lesson taught in the class. Refer session 2 of Module 3.

Check Your Progress

Multiple Choice Questions

1- Soil health is the manifestation of

a) Soil physical properties

b) Soil chemical properties

c) Soil biological properties

d) All of the above

2- Which one is not the criteria of good soil health indicators?

a) Sensitive to variations in climate and management

b) Measure changes in soil function

c) Comprises chemical, biological, and physical properties

d) Hard to measure

3- How many are essential soil functions listed?

a) 5
b) 3
c) 8
d) 4

4- World soil day is celebrated on the birthday of

a) King of North Korea

b) King of Thailand

c) Kind of China

d) Kind of Magadha

5. How many soil indictors listed in the soil health card

a) 10

b) 12

c) 5

d) 4

Fill in the Blanks

1. Word soil day is celebrated on ……
2. The united nation declared the Year 2015 as ……

3. Best pH range for crop growth is closed to ..... pH
4. Molybdenum is generally deficient in .....
5. Fungi adapt to ..... pH range.

True or False

1. Soil directly provides 78% of the food consumed by the human.
2. Nutrient cycling is not an essential function performed by the soil.
3. In India, the livelihood of about 60% of the population depends upon agriculture.
4. "Soil quality" and "soil health" cannot use interchangeably.
5. Soil is the dynamics heterogeneous porous natural material.

Session 2: Preparation of Soil Health Card

The Soil Health Card scheme is a Government of India (GoI) initiative and promoted by the Department of Agriculture, Co-operation & Farmers Welfare under the Ministry of Agriculture & Farmers Welfare. Across the country, it is being implemented through the various States and Union Territory Agriculture Department. The Government of India has developed a web portal (https:/www.soilhealth.dac.gov.in) for soil sample registration, data entry and printing of the SHC. The preparation of SHC started with the information collected at the time of soil samples collection (Table 1).

Table 1: Information Gathered at the Time of Collection of Soil Sample

Farmer's Name: .....

Village: ..... Taluka: ..... District: .....

Information of land holding:

Khasara no. of field under soil sampling: .....

GPS reading of said *khasara* no:

1. Longitude: ..... Latitude: .....
2. Longitude: ..... Latitude: .....

Area of field: .....

Name of Farm: .....

Geography of Land: Levelled / Undulated / Low line

Irrigated / Unirrigated: Well/Tube Well/Canal

Crop grown in Last Season: Kharif: ..... Rabi: ..... Summer: .....

Crop to be taken in next season: Kharif: ..... Rabi: ..... Summer: .....

Main Crop of this particular area:

1..... 2..... 3..... 4.....

Date of sampling: .....

Signature of soil sample drawer

Name: .....

Designation: .....

Farmer's Signature

Soil health card application consists of five major modules:

- User Registration and its approval by State Administrator
- Sample Registration
- Test Result Entry by Analyst
- Fertilizer Recommendation
- Soil Health Card Generation

User registration and its approval by state administrator

For the user registration, one has to look into http://soilhealth.dac.gov.in/, and click on ***login,*** as shown in figure 3.6. Then select your state and click into the Data entry. The first step in SHC generation through the soil health card web portal is registering a new sample.

Registration option

Now enter the information regarding User Organization Details, Language, User Details, User Login Account Details, User role, email address and mobile number etc. More than one role can be assigned to a single user. In this case, the user has selected such as Sample Registration, Lab In-charge, Analyst, Fertilizer Recommendation, MIS & Directories update and District MIS Users

roles etc. After entering all the information, click on the 'Submit' button and the form will be submitted to the state level authority for their approval. If all the entries of the form are correct, the message '**Your account creation request has been submitted**' will be displayed on the screen. Once the state level authority approves it, then we will login into the soil health card website.

will be submitted to the state level authority for their approval. If all the entries of the form are correct, the message '**Your account creation request has been submitted**' will be displayed on the screen. Once the state level authority approves it, then we will login into the soil health card website.

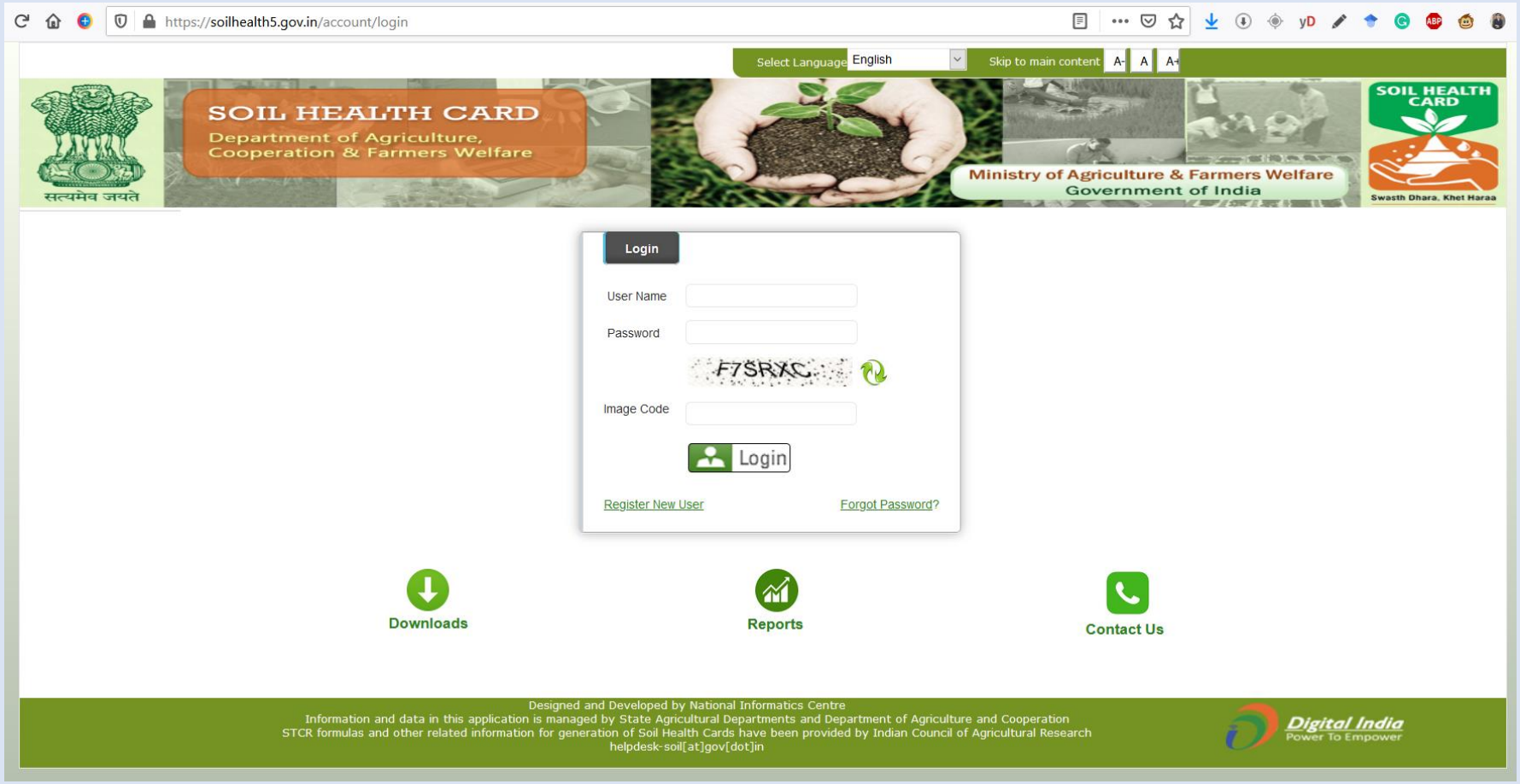


Fig. 3.7: View of new registration page of soil health card portal of Government of India.

Sample registration

The sample registration can be done only after the approval of the State Administrator. We need to follow the steps for the sample registration. These steps are:

- **Click on 'New Sample Registration' after the login**

  The screen for data entry would be displayed (Figure 3.7). The data entry form has been simplified to capture the minimum required fields.

  - Enter the sample details.
  - Enter crop details. (Details of Maximum of six crops can be entered for a Farmer).
  - Enter the number of Farmers connected with the Grid.
  - Enter the Details-Farmer, Land and Fertilizer use by the first farmer of the grid.
  - While entering the name of the farmer in Local Language, press space bar after entering each part of the name (First name, Middle Name and Last Name) and then that part will be converted into the local language selected by the sample registration user at the time of their "**User Registration**."
  - A farmer in a composite sample can ask for fertilizer recommendation for a maximum of six crops. Information regarding fertilizer availability in farmer's locality is collected in two combinations of fertilizers.

The first one is three fertilizers containing one major nutrient-N, P or K- each (by default Neem Coated Urea, Single Superphosphate (SSP), and Muriate of Potash (MOP) and second combination containing one complex fertilizer (Di-Ammonium Phosphate) and two single-nutrient fertilizers [Neem Coated Urea and Potassium Chloride (Muriate of Potash)]. Change the fertilizers where ever required.

- **Click on**

  - **Save button** to save the current farmers data and continue with the entry of details of the next farmer of the same grid. If 'Save" button is pressed after entering the details of the farmers of the composite sample, those sample details will be available under "Registered Samples".
  - **Enter next sample** to save the current Sample details and to enter the data of the next Sample [Previous Samples Details, Crop Details are retained. Change the data wherever required

- **Enter test result** to save the current Sample details and to go directly to Test Result Entry Screen and enter the Test Result for the current Sample
- **Refresh button** to cancel the entry in the form

➢ **Test result entry**

Test Result Entry is done in three ways: -

1. Directly from Sample Registration Screen- For the current sample- using Enter Test Result button.
2. Select the role of Analyst from the combo box displayed on the left top of the screen, click on 'Test Result Entry' and Search for the sample in the search box by giving any of the listed parameters.
3. Select the Analyst role from the combo box displayed on the left top of the screen, click on 'Test Result Entry'. If the Sample Number (only last number) is known in advance, it can be entered in the 'New Test Result Entry', and the corresponding full sample number will be populated in the 'Sample No' below.

   Enter the test result for all twelve parameter fields. If any parameter is not being tested in the lab the corresponding field could be kept as blank. After entering the Test Result values in the corresponding fields click on

   - **Save button-** to save the current samples' test result entries. This can be edited later also.
   - **Submit** – to submit the Test Result Entries for next level of action (Fertilizer Recommendation)
   - **Submit and generate fertilizer recommendation** to save the test result entry for the current Sample and go directly to the Fertilizer Recommendation screen.

Fertilizer recommendation

Fertilizer Recommendation can be made in two ways: -

1. Directly from Test Result Entry Screen- For the current sample- using Submit and Generate Fertilizer Recommendation button.
2. Select Fertilizer Recommendation from the top left combo box, Click on Fertilizer Recommendation link and Search for the sample in the search box by giving any of the listed parameters (such as sample id).

All the farmers of the selected sample will be displayed. If the name of more than one farmer is shown then

- Select the first farmer. All the crops for this farmer would be displayed. The Status of all crops is shown 'Not Saved'.
- Click on the first crop.
- Select the available General Fertilizer Recommendation (GFR) for that crop from the list (If there is only one GFR available for that crop then that GFR will be selected by default).
- Recommendations for Major Nutrients, Recommended doses of Fertilizers of Major Nutrients, Amendments, Secondary Nutrients and Micro Nutrients are, by default, in collapsed mode. If these are to be viewed/edited, the corresponding Down Arrow Image (↓) may be clicked.
- Click on the Save button to save the recommendation for the first crop. If the Crop, variety, Soil type, Irrigation Source etc. are the same for the other farmers of the same sample, then the recommendation of this crop for them also is saved**.**
    - Click on the next crop
    - Select the available GFR for that crop from the list. If there is only one GFR available for that crop, then GFR will be selected by default.)
    - Recommendations for Major Nutrients, recommended doses of Fertilizers of Major Nutrients, Amendments, Secondary Nutrients and Micro Nutrients are calculated by the system and displayed, by default, in collapsed mode. If these are to be viewed/edited, corresponding Down Arrow Image (↓) may be clicked.

➢ **Click on**

- **Save button-** Save button to save the recommendation for the selected crop. If the Crop, Variety, Soil type, Irrigation Source etc. are the same for the other famers of the same sample, then the recommendation of this crop will also be saved. This Save button should be clicked for all crops except the last crop of each farmer.
- **Submit button-** Submit button if the crop is the last one in the crop list of a farmer. This button helps to save and submit the Fertilizer Recommendation so that Soil Health Card (SHC) could be generated later. If the Crop, Soil type, Irrigation Source etc. are the same for the other famers of the same sample, then the recommendation of this crop will also be submitted.

- **Generate button-** Generate Soil Health Card button to submit the current sample and then go directly to SHC generation screen
- **Cancel button-** Cancel button to cancel the entries

Soil health card (SHC) generation: SHC could be generated in two ways: -

Directly from Fertilizer Recommendation Screen- For the current sample using Generate Soil Health Card button.

1) Select Fertilizer Recommendation Role from the top left Combo box

   a) Click on the Soil Health Card link.

   b) Select the Language, Area Unit, Sample Number, Farmer etc. from the Combo boxes available in the SHC Screen.

   c) Click on 'All Farmers' to generate SHC of all farmers connected with a Sample or select the farmer's name for generating his Soil Health Card.

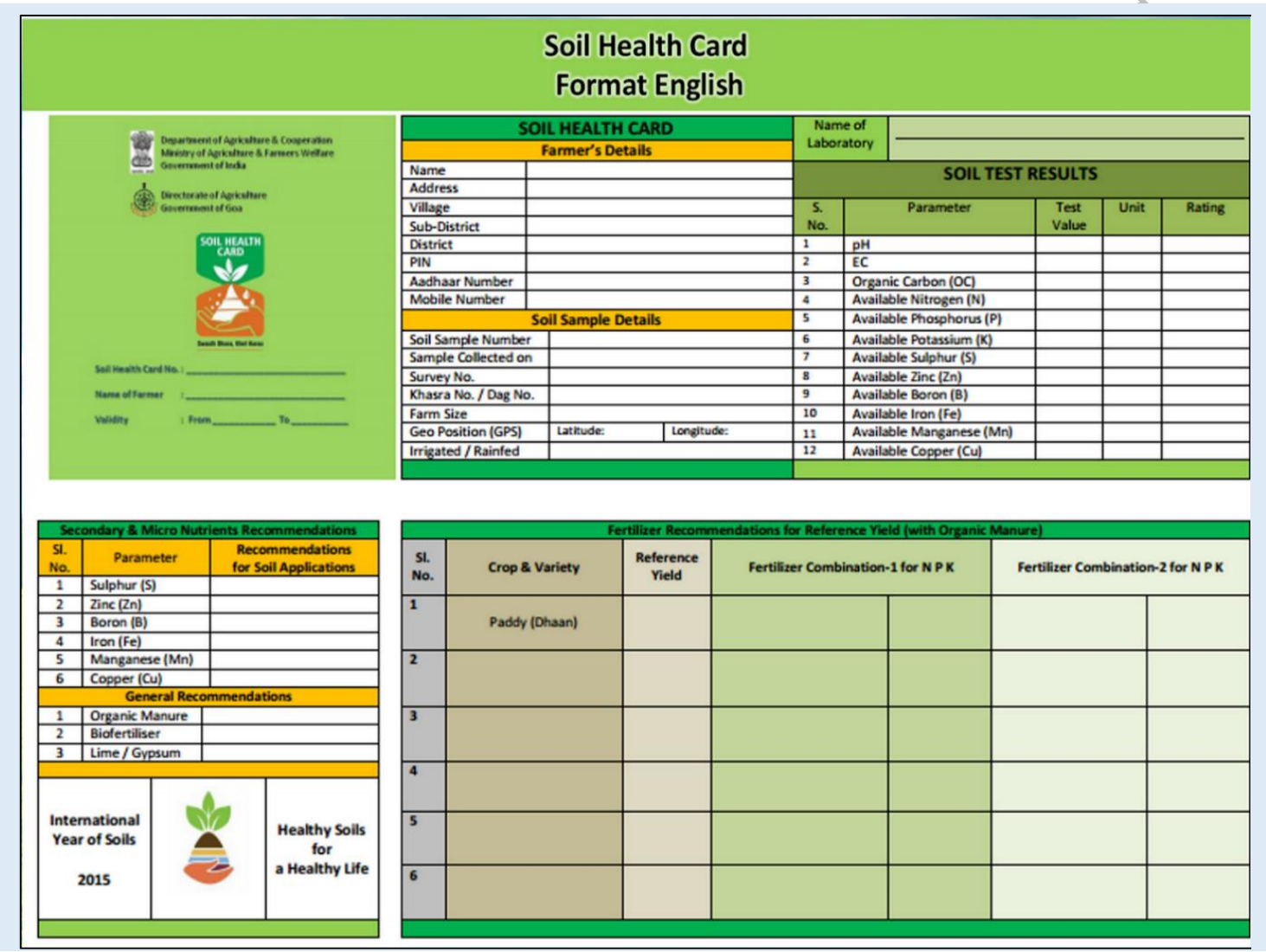
The Soil Health Card could be exported into 'pdf' by clicking the Export button and then selecting the file type. It will be saved automatically into the 'Download folder'. The default file name would be a combination of State code, village code, financial year and sample number.

Note:

For the preparation of soil health card, one sample per10 ha for dry lands and per 2.5 ha for irrigated lands is collected.

Soil Samples are taken generally two times in a year, after harvesting of Rabi and Kharif crops or when there is no standing crop in the field.

Figure 3.8 shows a representative picture of a blank Soil Health Card format as recommended by the Government of India and Fig 3.9 shows what a filled Soil Health Card looks like.



Soil Health Card
Format English

Department of Agriculture & Cooperation
Ministry of Agriculture & Farmers Welfare
Government of India

Directorate of Agriculture
Government of Goa

SOIL HEALTH CARD

Soil Health Card No. : _____

Name of Farmer : _____

Validity : From _____ To _____

SOIL HEALTH CARD			Name of Laboratory	
Farmer's Details				
Name			**SOIL TEST RESULTS**	
Address				
Village			S. No.	Parameter
Sub-District				
District			1	pH
PIN			2	EC
Aadhaar Number			3	Organic Carbon (OC)
Mobile Number			4	Available Nitrogen (N)
Soil Sample Details			5	Available Phosphorus (P)
Soil Sample Number			6	Available Potassium (K)
Sample Collected on			7	Available Sulphur (S)
Survey No.			8	Available Zinc (Zn)
Khasra No. / Dag No.			9	Available Boron (B)
Farm Size			10	Available Iron (Fe)
Geo Position (GPS)	Latitude:	Longitude:	11	Available Manganese (Mn)
Irrigated / Rainfed			12	Available Copper (Cu)

Test Value	Unit	Rating

Secondary & Micro Nutrients Recommendations		
Sl. No.	Parameter	Recommendations for Soil Applications
1	Sulphur (S)	
2	Zinc (Zn)	
3	Boron (B)	
4	Iron (Fe)	
5	Manganese (Mn)	
6	Copper (Cu)	
General Recommendations		
1	Organic Manure	
2	Biofertiliser	
3	Lime / Gypsum	

International Year of Soils 2015

Healthy Soils for a Healthy Life

Fertilizer Recommendations for Reference Yield (with Organic Manure)						
Sl. No.	Crop & Variety	Reference Yield	Fertilizer Combination-1 for N P K		Fertilizer Combination-2 for N P K	
1	Paddy (Dhaan)					
2						
3						
4						
5						
6						

Fig. 3.8: A blank Soil Health card as recommended by the Government of India

Secondary and Micronutrients Recommendations			
Sl. No.	**Parameter**	**Fertilizer Recommendations for Reference Yield (wi**	
		Through Soil	**Through Spray**
1	Zinc (Zn)	Zinc sulphate (15 - 25 kg/ha)	0.5% Zinc sulphate +0.25% lime
2	Iron (Fe)	Ferrous sulphate (25-50 kg/ha) (Soil application is preferred)	1% Ferrous sulphate (Spray thr
3			
4			
5			
General Recommendations			
1	Lime / Gypsum		

Department of Agriculture, Cooperation and Farmers Welfare

Ministry of Agriculture and Farmers Welfare

Government of India

Department of Agriculture, Karnataka Government

Soil Health Card

Soil Health Card Number -KA/2017-18/22929276/2

Validity- From: 10/09/2017 To:09/09/2019

Farmer's Details	
Farmer Name	**KONAVVA KATTANAVAR**
Father Name	YALAPPA
Address	Lane 1, Adagal, Badami, BadamiTahsil, Bagalkot, Karnataka
Mobile No.	981114035

Department of Agriculture, Karnataka Government

- Excess use of Fertilizer is injurious to soil health and plant growth. Use fertilizer judiciously.
- Reclaim Sodic Soil with Gypsum
- Treat acidic soil with Lime
- Organic Manures improve Soil Health
- Use Saline water after mixing with canal water
- Use Sodic water after treating with gypsum
- Adopt Integrated Nutrient Management for maintaining soil health& enhancing farm income

Kisan toll free number: 1800-180-1551

Website: https://soilhealth.dac.gov.in

Gender: Male	Category: General

Soil Sample Details

Date of Sample Collection	10/09/2017
Survey No., Khasra No./ Dag No.	88
Farm Size, Irrigation Status	2.16 Acre Irrigated (Bore well)
Geo Position (GPS)	Latitude 16.117223°N Longitude 75.800556°E

Soil Test Results

Soil Health Centre, Bagalkote

Soil Type: Black Soil

	Parameter	Test Value	Unit	Rating	Normal Level
1	pH	7.70		Moderately alkaline	7, Neutral

2	EC	0.04	dS/m	Normal	0-1 dS/m
3	Organic Carbon (OC)	0.35	%	Low	0.51-0.75%
4	Available Nitrogen (N)	200.6	kg/ha	Low	280-560 kg/ha
5	Available Phosphorus (P)	4.19	kg/ha	Very Low	23-57 kg/ha
6	Available Potassium (K)	122.8	kg/ha	Low	145-337 kg/ha
7	Available Sulphur (S)	26.50	ppm	Sufficient	> 10 ppm
8	Available Zinc (Zn)	0.27	ppm	Deficient	> 0.6 ppm
9	Available Boron (B)	0.63	ppm	Sufficient	> 0.5 ppm
10	Available Iron (Fe)	0.71	ppm	Deficient	> 4.5 ppm
11	Available Manganese (Mn)	6.41	ppm	Sufficient	> 2.0 ppm
12	Available Copper (Cu)	1.65	ppm	Sufficient	> 0.2 ppm

S No.	Crop & Variety	Reference Yield	Crop Stage	Organic Fertilizer	Biofertilizer	Fertilizer Combination-1 (kg/ha)		Fertilizer Combination-2 (kg/ha)	
1	Maize	24 q/a		FYM 13 t/ha	Azospirillum 0.500 kg/ha	Neem Coated Urea	435	Diammonium Phosphate (16:44:0)	284
						Single Superphosphate (SSP)	781	Neem Coated Urea	336
						Muriate of Potash (MOP)	67	Muriate of Potash(MOP)	67
2	Bajra (Pearl Millet)	15 q/a		FYM 8 t/ha	Azospirillum 0.500 kg/ha	Neem Coated Urea	289	Diammonium Phosphate (16:44:0)	236
						Single Superphosphate (SSP)	650	Neem Coated Urea	207
						Muriate of Potash (MOP)	42	Muriate of Potash (MOP)	42
3	Wheat	16 q/a		FYM 10 t/ha	Azospirillum 3.000 kg/ha	Neem Coated Urea	289	Diammonium Phosphate (16:44:0)	284
						Single Superphosphate (SSP)	781	Neem Coated Urea	190
						Muriate of Potash (MOP)	83	Muriate of Potash(MOP)	83

4	Bengal Grams (Gram)	10 q/a		FYM 10 t/ha	Rhizobium 1.250 kg/ha	Neem Coated Urea	72	Diammonium Phosphate (16:44:0)	191
						Single Superphosphate (SSP)	525	Neem Coated Urea	5
						Potassium Chloride (Muriate of Potash)	83	Muriate of Potash(MOP)	83
5	Green Grams (Moong)	3 q/a		FYM 10 t/ha	Rhizobium 0.500 kg/ha	Neem Coated Urea	37	Diammonium Phosphate (16:44:0)	95
						Single Superphosphate (SSP)	263	Neem Coated Urea	4
						Muriate of Potash (MOP)	42	Muriate of Potash(MOP)	42
6	Jack Fruit		1-3 years	FYM 3 t/acres		Neem Coated Urea	578	Diammonium Phosphate (16:44:0)	181
						Single Superphosphate	500	Neem Coated Urea	515
						Muriate of Potash(MOP)	166	Muriate of Potash(MOP)	166
			4-7 years	FYM 67 kg/plant		Neem Coated Urea	1156	Diammonium Phosphate (16:44:0)	363
						Single Superphosphate	1000	Neem Coated Urea	1030

						Muriate of Potash(MOP)	3333	Muriate of Potash(MOP)	333
			Above 7 years	FYM 67 kg/plant		Neem Coated Urea	1734	Diammonium Phosphate (16:44:0)	454
						Single Superphosphate	1250	Neem Coated Urea	1576
						Muriate of Potash (MOP)	501	Muriate of Potash(MOP)	501

Fig. 3.9: An example of filled-in SHC.

Rating of indicators as per the SHC

In SHC, a total of 12 soil health parameters are included. These soil health indicators are Nitrogen (N), Phosphorus (P) and Potassium (K); Sulphur (S); Zinc (Zn), Iron (Fe), Copper (Cu), Manganese (Mn) and Boron (B); Acidity or Alkalinity of soil (pH), Soil Electrical Conductivity (EC), and Organic Carbon (OC). The rating used for these 12 indicators during soil health card preparation is presented in Table 1. A general recommended dose of different micronutrient for soil and foliar application is also shown in Table 2.

Table 1. The Range of Different Indicator as Given in the SHC

S. No.	*Soil health Indicator*	*Range*
1.	Soil pH	Acidic <6.5 Normal 6.5-8.2 Alkaline >8.2
2.	EC (ds/m)	Normal <1 Medium 1-3 Harmful >3
3.	Organic Carbon (%)	Low <0.5 Medium 0.5-0.75 High >7.5
4.	Available Nitrogen (kg /ha)	Low < 280 Medium 280-560 High >560
5.	Available Phosphorus (kg/ha)	Low < 28 Medium 28-56 High >56
6.	Available Potash (kg/ha)	Low < 140 Medium 140-280 High >280

7.	Sulphur (ppm)	Low < 10 Medium 10-20 High >20
8.	Calcium (ppm)	Low < 1.5 Medium 1.5-3.0 High >3.0
9.	Zinc (ppm)	Low < 0.5 Medium 0.5-1.0 High >1.0
10.	Iron (ppm)	Low < 5 Medium 5-10 High >10
11.	Manganese (ppm)	Low < 5 Medium 5-10 High >10
12.	Copper (ppm)	Low < 0.2 Medium 0.2-0.4 High >0.4

Colour code used in soil health for rating of indicators:		
Color code	*** Green**	**Sufficient (General recommendation dose (-) 30%)**
	Yellow	**Moderate (General recommendation dose)**
	Red	**Deficient (General recommendation dose (+) 30%)**
	#Violet	**Acidic/Sodic/Alkaline**

Agencies responsible for soil testing

The soil sample will be tested as per the approved standards for all the agreed 12 parameters in the following ways:

- At the soil test laboratories (STLs) owned by the Department of Agriculture and by their own staff.
- At the STLs owned and outsourced by the Department of Agriculture.
- At the STLs owned by the outsourced agency and by their staff.
- At ICAR Institutions including KVKs and SAUs.
- At the laboratories of the Science Colleges/Universities by the students under the supervision of a Professor/ Scientist.

Expenses involved in soil testing

An amount of Rs. 190 per soil sample is provided to State Governments by the GoI. This covers the cost of collection of soil sample, its testing and generation as well as distribution of soil health card to the individual farmer.

Table 2. General Recommended Dosages for Application of Micronutrient Fertilizers

S. No.	Micronutrient	Material	Content (%)	Soil Application	Foliar application
1.	Zinc (Zn)	Zinc sulphate ($ZnSO_4.7H_20$)	21	25 kg/ha	0.5% Zinc sulphate + 0.25% lime
2.	Iron (Fe)	Ferrous sulphate ($FeSO_4.7H_20$)	19	50 kg/ha	1% Ferrous sulphate + 0.5% lime
3.	Copper (Cu)	Copper sulphate ($CuSO_4.5H_2O$)	24	10 kg/ha	0.1% copper sulphate + 0.05% lime

4.	Manganese (Mn)	Manganese sulphate ($MnSO_4.H_2O$)	30.5	10 kg/ha	1% Manganese sulphate + 0.25% lime
5.	Boron (B)	Sodium borate (borax) $(NH_4)_6Mo_7O_{24}.24H_2O$	10.5	10 kg/ha	0.2% borax

Check Your Progress

Multiple Choice Questions

1-A high soil organic carbon improves

a) Water availability
b) Soil fertility
c) Soil structure
d) All of the above

2- Which one is the secondary plant nutrient?

a) Nitrogen
b) Phosphorus
c) Potassium
d) Sulphur

3- Soil health card scheme was started on

a) 19 February 2015
b) 5 December 2015
c) 26 January 2015
d) 15 August 2015

4- Soil health card provides how many sets of fertilizer recommendation.

a) 2 sets
b) 3 sets
c) 4 sets
d) Single sets

5. Nitrogen use efficiency in India varies from

a) 30-50%
b) 70-90 %
c) 100 %
d) 0-30 %

Fill in the Blanks

1. The soil health cards provide fertilizer recommendation for ……. crops.
2. For the preparation of soil health card in dryland area, one sample is collected from …… hectares.
3. For the preparation of soil health card in the irrigated area, one sample is collected from …… hectares.
4. The government of India gives Rs……../- per sample to state government for soil sample analysis and soil health card preparation.
5. General recommended dose of zinc application in the soil is ….

True or False

1. Yellow colour in soil health cards is an indicator of deficient of particular nutrient content.
2. Violet colour indicates sufficient of particular nutrient content.
3. The range of high organic carbon (%) in soil health card is 0.5-0.75.
4. In soil health card, the recommendation of any number of the crop can be provided.
5. Soil samples must be taken after harvesting of Kharif and Rabi crops.

Module 4
Water Quality Report and Interpretation

Module Overview

Water is a very precious resource for the survival of all living organisms on the planet. Water (H2O) is the fundamental basis of life". Therefore, good quality of water is essential for all purposes including drinking, agriculture, domestic, industrial etc. However, due to over exploitation of water resources, its quality has deteriorated over time. In this Module you will study about the concept of water quality, water quality report generation and its interpretation.

Learning Outcomes

After completing this module, you will be able to:

- Explain the concept of water quality, including key indicators such as pH, dissolved oxygen, salinity, and contaminant levels, and their importance for agricultural and environmental sustainability.
- Describe the process for preparing a water quality report, including data collection, analysis of water samples, interpretation of results, and providing recommendations for water management practices to
- maintain and improve water quality.

Module Structure

- Session 1: Concept of Water Quality
- Session 2: Preparation of Water Quality Report

Session 1: Concept of Water Quality

Water quality means the status of its physical, chemical, and biological characteristics and its suitability for drinking, irrigation or any other purposes.

1.1 Water quality in relation to agriculture

Water quality is one of the most important factors of a healthy ecosystem. The quality of water is affected by the presence of suspended unwanted materials, excessive nutrients, pesticides and harmful microorganisms. Poor water quality poses a health risk, whereas good quality water supports healthy plants and animals in an ecosystem. Water quality plays an important role in agriculture as described below:

1. Good quality irrigation water is vital for maintaining soil health and crop productivity, whereas continuous use of poor-quality water for irrigation makes the soils less productive.
2. Use of marginally saline water sometime improves plant growth due to salt/nutrients concentration in it. However, its prolonged use leads to excessive accumulation of salts on the surface layers and makes the soil unsuitable for crop production and becomes barren.
3. Use of tube-well or well waters have the problem of excessive salinity as compared to canal water. Therefore, it is always advisable to test the water quality before use.
4. Use of poor-quality water in agriculture, adversely affects the plant nutrient availability in soil and deteriorates the soil physical structure that leads to a decrease in overall soil health.

1.2 Water quality parameters

Water quality is represented by its physical, chemical and biological parameters. These parameters are greatly influenced by various activities, such as agricultural, industrial and human activities. To understand the water quality, it is important to test or analyses its properties.

Major causes of water pollution: The major sources of water pollution are described in the Figure 4.3.

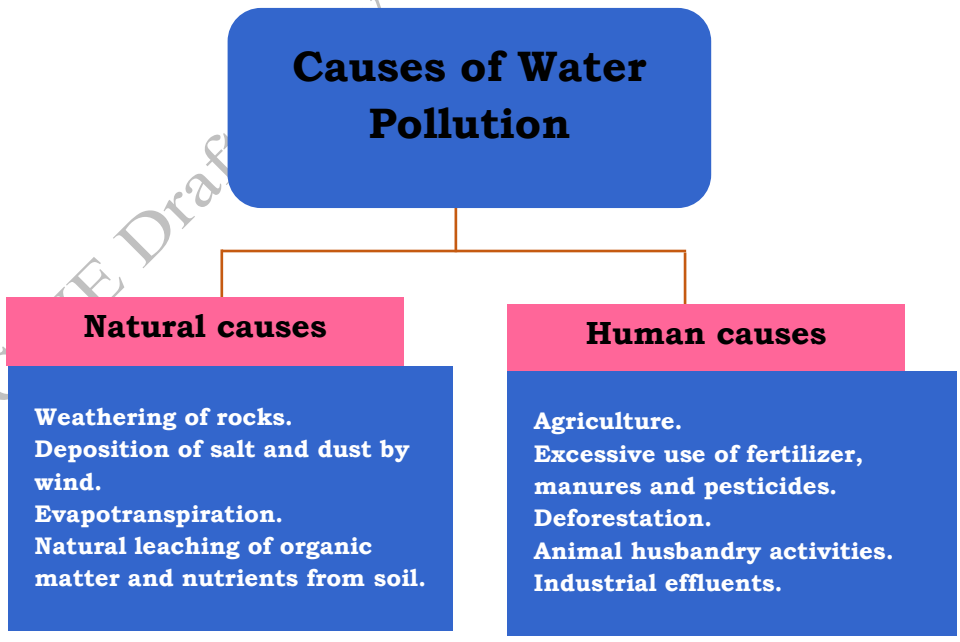


Fig 4.3: Major causes of water pollution

Water testing is conducted for:

- Quantitative assessment of the salts of nitrate, chloride, sulphate, carbonates and bicarbonates of sodium, calcium, magnesium and potassium, salts of fluorine, and boron.
- Presence of harmful organic compounds and toxic heavy metals.
- Concentration of dissolved oxygen.
- Presence of microorganisms.
- Amount of material suspended in the water (turbidity).

However, to reach correct conclusions about the quality of water for agricultural use we mainly test the water quality in terms of the following major criteria (Figure 4.4)

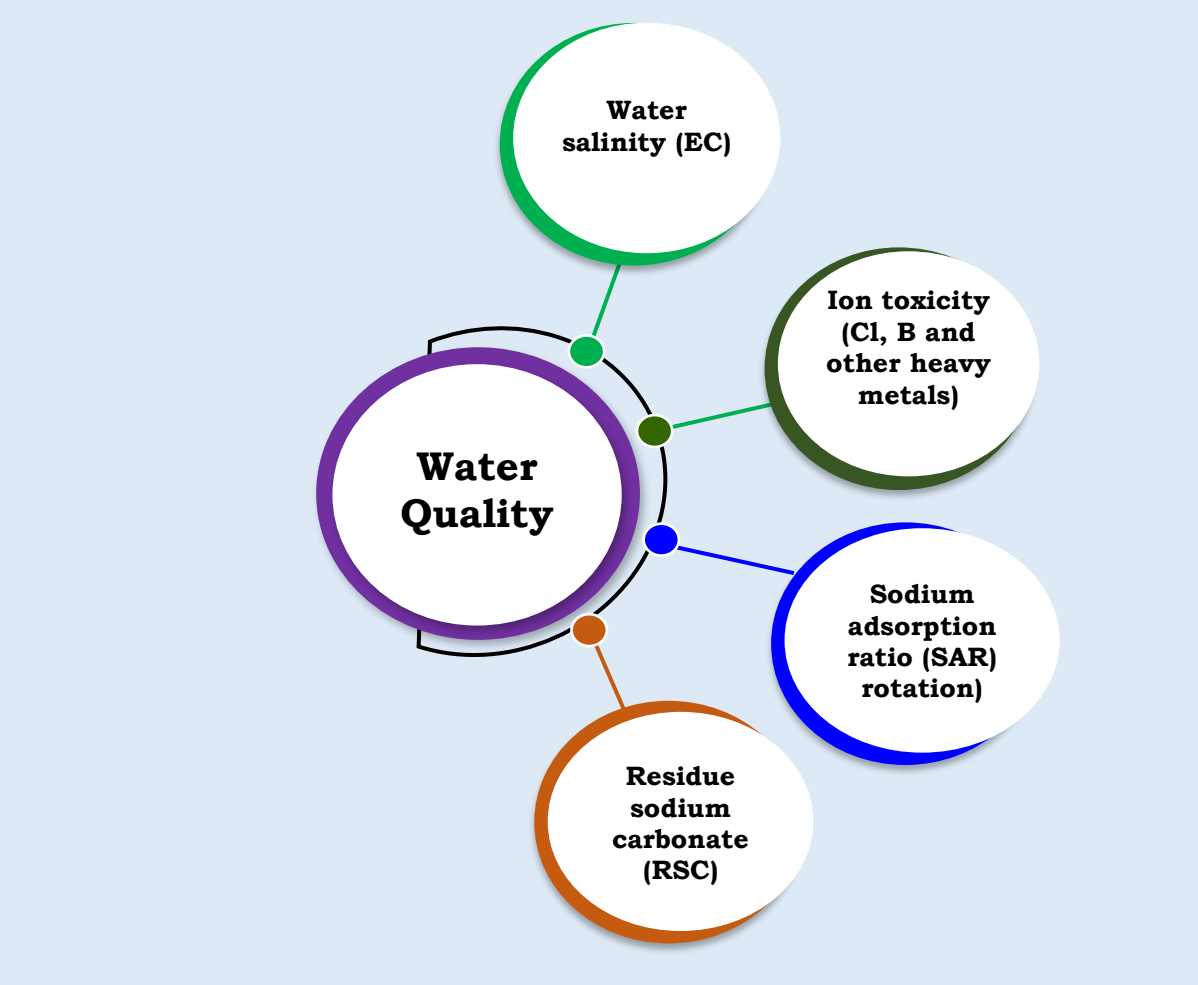


Fig. 4.4: Basic criteria for determining water quality for irrigation

Water Quality Parameters: The different water quality parameters are shown in Figure 4.5.

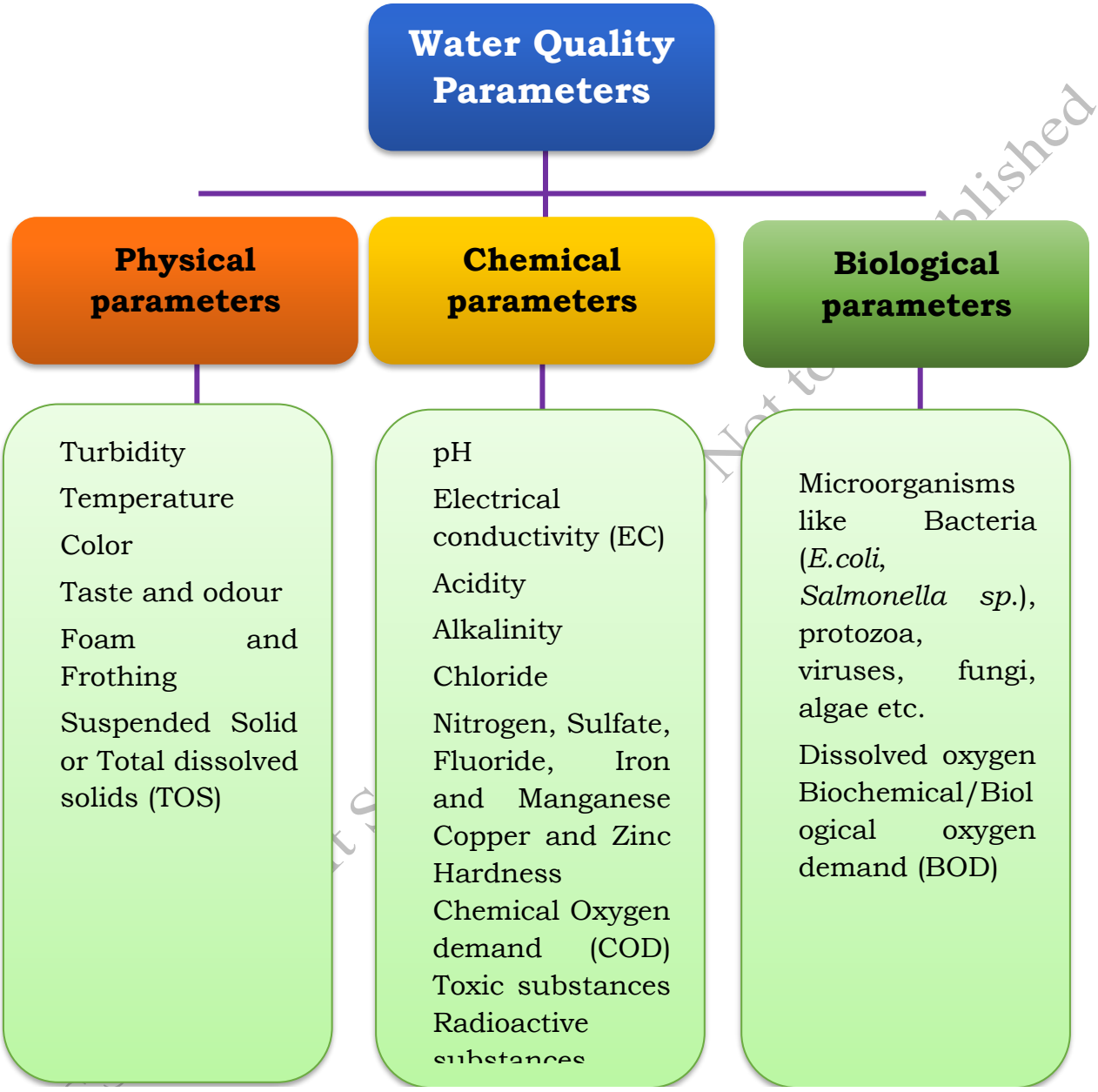


Fig.4.5: Water quality parameters

Physical parameters

Water quality is determined based on the physical parameters like turbidity, temperature, colour, taste and odour, foam and frothing and suspended solid or total dissolved solids (TOS).

Chemical parameters

Water quality is determined based on the following chemical properties namely,

- pH (acidity and alkalinity) and EC (salinity)
- Dissolved load of chemical constituents especially nitrate, phosphorus, fluoride, arsenic, heavy metals, pesticides and other toxic compounds.

Water testing is mostly focused on the quantitative assessment of these compounds in water. Water analysis is also carried out to study the harmful organic compounds in it. Water quality is also related to soil health and environmental quality. Too many nutrients in the water can cause excess growth of algae. Pollutants such as metals, oils, pesticides, and other harmful chemicals cause harmful effect on human health.

Biological parameters

Like chemical properties, biological properties for water quality is assessed through some parameters of water such as dissolved Oxygen including Biological/ Biochemical oxygen demand (BOD) and Chemical Oxygen Demand (COD) (the amount of oxygen dissolved in water) and coliform bacteria (example: *E.coli*)

Biological oxygen demand (BOD)

Biological oxygen demand is a measure of the amount of oxygen required to remove waste organic matter from water in the process of decomposition by aerobic bacteria. It is considered a good index of organic pollution which means that if the BOD of the water is more, it is more polluted. The high amount of organic matter in a water sample means higher oxygen demand by the microorganisms (bacteria, fungi etc.) to decompose this organic matter.

Chemical oxygen demand (COD)

It is the measure of amount of oxygen that can be consumed by reaction in a solution. It is a test of the amount of organic and inorganic substance that can be chemically oxidised. This test is based on the fact that a strong oxidising agent under acidic conditions can fully oxidise almost any organic pollutant to CO_2. This means that if the amount of organic pollutants in a water body is more the COD would be more. The COD test is often used as an alternate to BOD due to shorter length of testing time. It is expressed in mg/L which indicates the mass of oxygen consumed per unit litre of water.

Water quality classification

Water quality is classified into four major types *viz.,* potable water, palatable water, contaminated (polluted) water, and infected water. The most common ways of expressing these types of water are as follows:

1. **Potable water:** Safe to drink, pleasant to taste, and usable for domestic purposes.
2. **Palatable water:** Aesthetically pleasing and the presence of chemicals in it don't cause a threat to human health.
3. **Contaminated (polluted) water:** Water containing unwanted physical, chemical, biological, or radiological substances, and unfit for drinking or domestic use.
4. **Infected water:** Contaminated water with pathogenic organisms present in it.

Activities

Take 4 glass jars and collect water samples from four different sources *viz.,* tube well, bore well, lake and pond in each jar, respectively. Observe the quality of water in each jar and record its colour, suspended solids and any other impurities present in them. Discuss your findings with your friends.

Requirements: Glass jars, glass stirrer, labels, observation note-book.

Step by step process: Divide yourselves in a group of four and under the supervision of your teacher follow these steps:

- Collect water samples from nearby tube well, bore well, lake and pond in 4 glass jars, respectively. Keep a separate glass jar filled with distilled water as control.
- Label the glass jars properly.
- Make sure that sufficient and equal amount of water samples are collected in all the glass jars.
- Bring them to the laboratory, stir the samples and let them rest so that the impurities and suspended particles can settle down.
- Record your observations in the observation note-book.
- Discuss your findings in the class.

Check Your Progress

Multiple Choice Questions

1. Water quality is judged by which of the following properties
   a) Physical
   b) Chemical
   c) Biological
   d) All of the above
2. The basic purpose of water testing in agriculture is-
   a) Suitability for irrigation purpose
   b) Drinking purpose
   c) Domestic use
   d) All of the above
3. Poor quality water may be harmful for
   a) All living forms in the soil
   b) Crop health
   c) Animal health
   d) All of the above
4. Marginal use of saline water improves plant growth due to presence of
   a) Salt of essential nutrient
   b) Salt of heavy metals
   c) Agrochemicals
   d) All of the above
5. Water testing is the quantitative assessment of soluble salts of
   a) Nitrate and chloride
   b) Bicarbonates of sodium and potassium
   c) Calcium and magnesium
   d) All of the above

Fill in the Blanks

1. Number of suspended materials present in the water is checked by its .....
2. Hardness of water is judged by presence of salts of .....
3. Salinity of water refers amounts of ..... present in the water
4. Dissolved oxygen required by aerobic bacteria to break down..... in a water sample at certain temperature.
5. The water testing is based on its physical, chemical and ..... parameters.

True or False

1. Presence of *E. coli* in the water is called the poor-quality water.
2. Water with high biological oxygen demand is good for irrigation purpose.
3. Water soluble Boron (ppm) content in water is <0.7 ppm is safe for crop growth
4. Gypsum is required for neutralizing the residual sodium carbonate (RSC) in the water.
5. Presence of micronutrients in excess amount is the improvement of quality of irrigation water.

Session 2: Preparation of Water Quality Report

Testing a water sample goes through many steps before it becomes part of the water quality data set. The following Figure (Figure 4.6) briefly describes all the steps leading to water quality report generation.

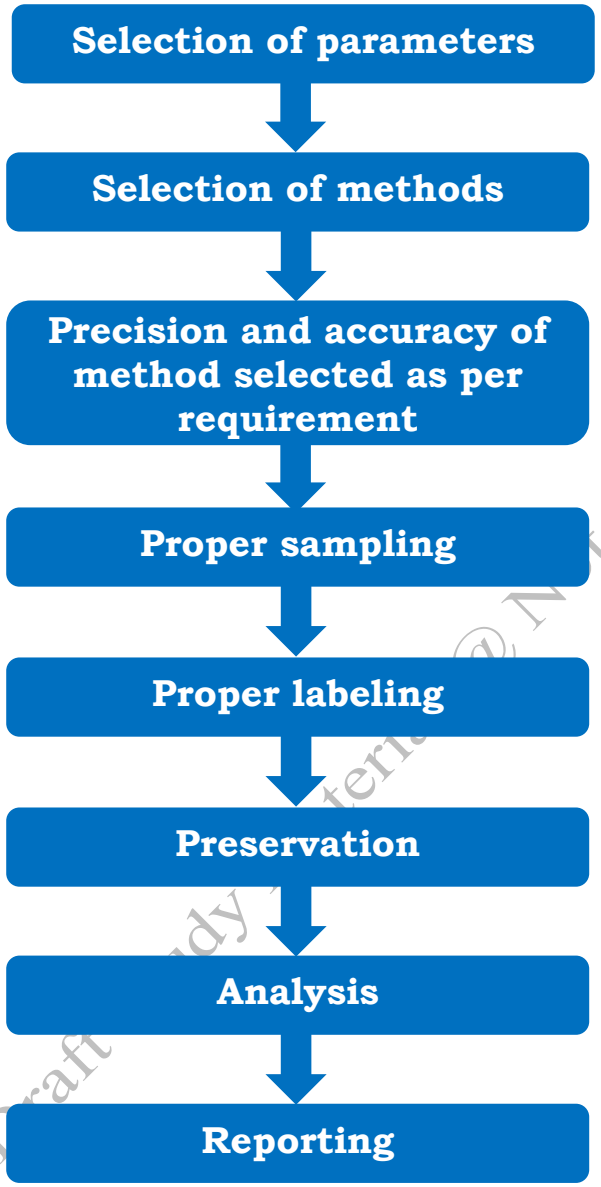


Fig. 4.6: Steps involved in generation of water quality report generation

There is potential for error at each of these steps. The major sources of error are adopted for better precision of results:

- Measurement error
- Sample handling error
- Location specific variability (Natural variability).

Following procedures are followed for better precision of results:

1. Quality control checks measured data quality.
2. Common checks include duplicate samples, blanks, reference samples, and performance audits.
3. Duplicate samples are two identical samples collected and handled in the same way. Generally, field and laboratory duplicates are followed to make the results more precise.

Do you know!

Blank samples

Blanks are the samples containing pure, uncontaminated water.

Reference standard samples

These contain a known concentration of the chemical you are measuring. Reference samples measure the accuracy of your laboratory analysis.

Data entry of water testing results

- The analyzed physical, chemical and biological properties of water samples are recorded in data sheets.
- Due care is taken to enter the data correctly.
- Incorrect entry leads to poor interpretation of results.
- If these steps are carried out without care, the entire process results in wastage of resources. Therefore, systematic data entry is essential.

Format of water sample analysis records

- The water testing laboratories keep records of submitted samples and completed analysis for easy retrieval of data.
- All laboratory data sheets are dated and signed by the concerned chemist/lab analyst and the laboratory manager.
- The following entries are done preferably at the respective laboratory:
  - Date of sample analysis:
  - Sample number/ID:
  - Parameter analyzed:

- Blank and reference sample:
- Readings or observations of different parameters:
- Results:
- Interpretation/Inference including its suitability of irrigation:

Rating of parameters

Similar to quality for drinking water, certain criteria are followed for irrigation purposes also. The quality of irrigation water is one of the important factors that affect the physical, chemical and biological properties of soil and eventually affect the crop growth. Moreover, the irrigation water must be free from soluble salts and certain chemical substances. The following criteria (Table 1) is followed for classifying irrigation water.

Table 1: Criteria for Classifying Irrigation Waters

Elements	Suitable	Moderately Suitable	Unsuitable
pH	6.5-8.4	8.5-9.5	>9.5
EC (milli Siemens per meter, mS/m)	25	25-75	>75
Sodium adsorption ratio (SAR)	<10	10-18	>18
Residual sodium carbonate (RSC, me/L)	<1.25	1.25-2.5	>2.5
HCO_3 (me/L)	<1.5	1.5-8.5	>8.5
NO_3-N (me/L)	<5.0	5.0-30.0	>30
Boron (me/L)	<0.75	0.75-2.0	>2.0
Chlorine (me/L)	<4.0	4.0-10.0	>10
Fluoride (me/L)	<1.0	1.0-15.0	>15

Parameters for assessing irrigation water quality

1. **pH:** It is an indispensable parameter for characterizing irrigation water or soil from the standpoints of nutrient availability. Irrigation water quality is also important aspects of crop production in agriculture. In fact, extreme high and low pH can be detrimental for the use of water. A high pH makes the taste bitter and decreases the effectiveness of the chlorine disinfection, thereby causing the need for additional chlorine. Extreme high and low pH adversely affects soil properties, nutrient availability and plant growth which in turn reflect on the soil health assessment.
2. **Electrical conductivity (EC)**: Electrical conductivity, represents the soluble salt content in the soil and water measured by a conductivity meter. Soils containing excess amount of neutral soluble salts dominated by chlorides and sulphates affect the various soil properties and plant growth. Determination of EC is very important in irrigation water and salt affected soil, in which salts may accumulate in quantities that are detrimental to soil health and crop production (Table 2).

Table 2: Range of EC and Salinity Level

EC ($\mu S\ cm^{-1}$)	Inference
<750	No detrimental effects are observed.
750-1500	May have some detrimental effects on sensitive crops.
1500-3000	Moderate adverse effects on many crops, thus requiring careful management practices.
3000-7500	Severe detrimental effects are observed on crops. This water may be used for salt tolerant plants on permeable soils with careful management practices.

3. Carbonates and Bi-Carbonates, Boron and Chloride in Water

- The presence of carbonate (CO_3^{2-}) and (bicarbonate (HCO_3^-) anions in water is an important criterion for judging the quality of irrigation water.
- The excess amount of these anions adversely affects the soil health and crop productivity.
- The residual sodium carbonate (RSC) is used to evaluate the quality of irrigation and is expressed in me/L^- (milliequivalent per liter).

Table 3: Water Quality Assessment Based on Bicarbonates Hazard

RSC values (me/L)	HCO_3 (me/L)	Water quality
<1.25	<1.5	Water can be used safely
1.25-2.5	1.5-8.5	Water can be used with certain management
>2.5	>8.5	Unsuitable for irrigation purpose

4. **Trace elements/Heavy metals:** Similar to pH and EC, the irrigation water may contain permissible limits of trace elements/heavy metals beyond which it may be detrimental to plant growth (Table 4).

Table 4: Permissible Concentration of Trace Elements/Micronutrients in Irrigation Water

Elements	Irrigation water quality (for use in all soil mg/L)
Copper (Cu)	0.2
Zinc (Zn)	2.0
Iron (Fe)	5.0
Manganese (Mn)	0.2

5. **Boron (B):** For irrigating water quality rating, water samples are not usually tested for B content. However, saline water of arid and semi-arid regions may have high concentration of B, which could be toxic depending upon the type of the minerals present in the soil. If the water contains excessive amount of B, it is unsafe or toxic to plants (Table 5).

Table 5: Water Soluble B Content and Crop Suitability

Boron concentration (ppm)	Effect on crops
< 0.5	Satisfactory for all crops
0.5–1.0	Satisfactory for most crops
0.5–1.0	Satisfactory for semi-tolerant crops
2.0–4.0	Satisfactory for tolerant crops only

6. Chloride (Cl^-)

- Chloride (Cl^-) ion is highly soluble in the water, but the amount is often very low in natural waters or rainwater.
- The chloride in the water increases due to excessive evaporation in the arid and semi-arid regions and develops due to chloride bearing minerals e.g. KCl, NaCl and $MgCl_2$. The chloride content in water for crop suitability is given in Table 6.

Table 6: Chloride Content in Water and Crop Suitability

Chloride concentration (meq/L)	Comments	Water quality	Crop suitability
<2	Nil	Excellent	Excellent for all crops
2-4	Low	Good to Very good	Crops can grow (safe)
4-10	Medium	Marginal	Slightly usable
>10	High	Not suitable for irrigation	Unsafe

7. Sodium absorption ratio:

- After analysis of water samples for different parameters like total salts (EC), cation and anions, it is essential to calculate and characterize some indices to assess the suitability of water quality.
- If you are able to calculate SAR, based on these values water can be grouped into different categories of sodality as explained in Table 7.

Table 7: Permissible Limits of SAR for Irrigation Purpose

Sodium Absorption Ratio (SAR Value)	Remarks
<10	Safe for irrigation
10-18	Moderately safe
19-26	Moderately unsafe for irrigation
>26	Unsafe for irrigation

Developing water quality report

- Once the laboratory analysis of water is completed, we need to prepare a report.
- The analysis report should be presented in systematic manner.
- It contains a list of nutrients and contaminants tested, the concentrations and in some cases problem contaminants are highlighted.
- An important feature of the report is that, that the units used to measure the contaminant level in the water samples and other substances like nutrients and constituents in it is in milligrams per liter (mg/L).
- Some values like pH, hardness, conductance, and turbidity are reported in units specific to the test.
- In addition to the test results, a lab may make notes on any contaminants that exceeded the permissible limits of drinking water.

Table 8: Water Parameter Symbol in their Unit

Parameter	Symbol	Unit	Equivalent weight
Acidity-Alkalinity	pH	--	-
Electrical Conductivity	EC	Desi siemens per meter (ds/m)	-
Calcium	Ca	me/L	20
Magnesium	Mg	me/L	12.2
Sodium	Na	me/L	23
Carbonate	CO_3	me/L	30
Bicarbonate	HCO_3	me/L	61
Chloride	Cl	me/L	35.5
Sulphate	SO_4	me/L	48
Boron	B	me/L	10.8
Nitrate-nitrogen	NO_3-N	me/L	14
Ammonium-nitrogen	NH_4-N	me/L	14
Phosphate	PO_4	me/L	31
Potassium	K	me/L	39.1
Iron	Fe	me/L	7
Fluoride	F	me/L	19

Interpretation and recommendation of water analysis.

- Once water analysis is completed, report preparation and recommendation are the important procedure against the submitted samples.
- Before handing over the report, it should be double checked for its accuracy.
- Some widely acceptable ratings are given below (Table 9). These critical values are taken as a general guideline and necessary recommendation are made depending upon the soil-crop situation.
- The report may contain information about the water quality indicating if it is within the 'permissible limit', 'moderately safe', 'safe' or 'unsafe' for irrigation (Table 9).

Table 9: Parameter Indicators within Permissible Limits

Parameter	Permissible	Moderately safe	Moderately unsafe	Unsafe
RSC (me/L)	< 1.25	—	1.25 - 2.50	> 2.50
SAR	< 10	10 – 18	18 – 26	> 26
Boron (mg/L)	< 2.0	2.0 - 2.5	2.5 •- 3.0	> 3.0
Chloride (mg L1)	< 140	140-350	-	> 350
BOD (mg of O_2/ L)	< 100	-	-	> 100

The summary of the of soil water quality parameters, their source, and problems caused by them is presented in Table 10

Table 10: A Summary of Soil Water Quality Parameters, their Source, and Problems Caused by them:

S. No.	Water quality parameters	Type	Sources	Problem caused
1.	Suspended solids (turbidity)	Physical	Soil particles through runoff and erosion; construction materials.	• Reduced photosynthesis in aquatic vegetation. • Interferes with respiration in aquatic animals.
2.	Different salts (combination of major cation: Ca^{2+}, Mg^{2+}, K^{+}, Na^{+} and major anions:CO_3^{2-}, HCO_3^{-}, SO_4^{2-} and Cl^{-})	Chemical	Ground water; evaporation of water from the surface water; Municipal, agricultural, and industrial discharge.	• Induces salinity in soil. • Creates condition for reverse osmosis with excess salts. • Reduces the crop productivity.
3.	Heavy metals such as zinc, arsenic, lead, mercury, cadmium, nickel	Chemical	Industrial discharge, landfills and runoff.	• Bioaccumulation in plant and animal tissue. • If exposed to higher concentration may lead to illness.

4.	Nutrients such as nitrogen and phosphorous etc.	Chemical	Excess fertilizer uses in agriculture .	• Induced Eutrophication (*Eutrophication* is a condition in which excessive growth of plant and algae is observed in water bodies due to the increased nutrient availability).
5.	Dissolved oxygen	Chemical	Air	• Low level is harmful for aquatic ecosystem
6.	Coliform bacteria	Biological	Human sewage, livestock wastes	• Causes diseases in humans.

The following table (Table 11) shows the maximum permissible limits of trace elements in irrigation water.

Table 11- Maximum Concentration of Trace Elements in Irrigation Water

Elements	Irrigation water (mg/L)
Manganese (Mn)	0.2
Lead (Pb)	5.0
Molybdenum (Mo)	0.01
Nickel (Ni)	0.2
Selium (Se)	0.02
Aluminum (Al)	5.0
Arsenic (As)	0.1

Copper (Cu)	0.2
Cadmium (Cd)	0.01
Cobalt (Co)	0.05
Iron (Fe)	5.0
Zinc (Zn)	2.0

Water sample collection

The procedure for water sample collection has been explained in Module 1 (Session 1). In addition to that, the following criteria are taken care of for recording every sample collected as shown in Figure 4.7

- Provided with unique code and Global Positioning System (GPS) coordinates.
- Each container is identified and information like date, time and exact location is recorded (block, habitation, panchayat, village, code number, weather conditions and stream flow etc.).

Collected samples are taken to the laboratory for analysis.

Name of the farmer/client: .....

Location: .....

Field number: .....

Cropping history: .....

Crop to be grown in the next season: .....

Date of collection: .....

Name of the sampler: .....

Any other information: .....

Fig. 4.7: Criteria for recording collected samples

Check Your Progress

Multiple Choice Questions

1- The level of Boron falls under 'suitable' category for irrigation water when it is in the range:

a. <0.75 me/L
b. >2.0 me/L
c. >10 me/L
d. None of the above.

2-pH level considered unsuitable for irrigation water is

a. 6.5-8.4
b. 8.5-9.5
c. >9.5
d. Both (a) and (b)

3- The maximum permissible concentration of Ni in irrigation water is

a. mg/L
b. 10 mg/L
c. 0.2 mg/L
d. None of the above

4-The water quality report is prepared

a. After the laboratory analysis of water sample.
b. Before the laboratory analysis of water sample.
c. During the laboratory analysis of water sample.
d. None of the above

5. The unit used for measuring the contaminates in water quality report is

a. mg/L
b. Kg/L
c. g/L
d. µg/L

Fill in the Blanks

1. The sodium adsorption ratio (SAR) value <10 for irrigation water is considered ……
2. If the chloride concentration ……me/L the water is considered not suitable for irrigation.
3. ……. ion is highly soluble in water.
4. The residual sodium carbonate (RSC) is expressed in …….
5. EC in the range ……has no detrimental effect on crops.

True or False

1. RSC> 2.5 is suitable for irrigation purpose.
2. Chloride content in the range 2-4 meq/L is considered safe for crop growth.
3. The moderately suitable SAR range for irrigation water lies in the range 10-18.
4. Date of sample analysis is not important in the water sample analysis record.
5. EC in the range of 3000-7500 µS/cm in irrigation water is considered best for growing crops.

Answer Keys

Module 1: Preparation of Soil and Water Samples for Analysis

Session 1: Setting up of Soil and Water Testing Laboratory

Multiple Choice Questions

1	a)	2	d)	3	c)	4	d)	5	a)

Fill in the Blanks

1	2 mm	2	representative	3	4°C	4	fresh	5	N

True or False

1	False	2	False	3	False	4	False	5	True

Session 2: Collection and Processing of Soil and Water Samples

Multiple Choice Questions

a)	2	b)	3	c)	4	b)	5	c)

Fill in the Blanks

1	Gypsum	2	Same	3	evaporate	4	Sample ID	5	Pestel and Mortar

True or False

1	False	2	True	3	False	4	True	5	True

Module 2: Instrument Calibration, Maintenance and Reagent Preparation

Session 1: Preparation of Primary and Secondary Standard Solutions

Multiple Choice Questions

1.	d)	2.	b)	3.	c)	4.	a)	5.	b)

Fill in the Blanks

1	Acceptable	2	Solute	3	chemical	4	Primary	5	24

True or False

1	False	2	False	3	False	4	False	5	True

Session 2: Calibration and Maintenance of Instruments in Soil and Water Testing Laboratory

Multiple Choice Questions

1	c)	2	d)	3	c)	4	b)	5	d)

Fill in the Blanks

1	7.0	2	Deionized	3	Accurate	4	Glass	5	200-700 nm

True or False

1	True	2	True	3	False	4	True	5	True

Module 3: Soil Health Card and Interpretation

Session 1: Concept of Soil Health

Multiple Choice Questions

1	d)	2	d)	3	a)	4	b)	5	b)

Fill in the Blanks

1	5th December	2	International year of soil	3	Neutral	4	Acidic soil	5	Large

True or False

1	True	2	False	3	True	4	False	5	True

Session 2: Preparation of Soil Health Card

Multiple Choice Questions

1	d)	2	d)	3	a)	4	a)	5	a)

Fill in the Blanks

1	Six	2	10	3	2.5	4	190/-	5	25 kg/ha

True or False

1	False	2	False	3	False	4	False	5	True

Module 4: Water Quality Report and Interpretation

Session 1: Concept of Water Quality

Multiple Choice Questions

1	d	2	a	3	d	4	a	5	d

Fill in the Blanks

1	Turbidity	2	Ca and Mg	3	Soluble salts	4	Organic matter	5	2.50

True or False

1	True	2	False	2	True	4	True	5	False

Session 2: Preparation of Water Quality Report

Multiple Choice Questions

1	a	2	c	3	c	4	a	5	a

Fill in the Blanks

1	Safe	2	>10	3	Chloride	4	Me/L	5	<750

True or False

1	False	2	True	3	True	4	False	5	False

Glossary

Analytical: It is relating to or using analysis or logical reasoning. It is the careful examination in order to understand or explain something.

Accuracy: Accuracy refers to how closely the measured value of a quantity corresponds to its true value.

Acidity: Acidity is the measure of hydrogen (H^+) ion concentration of a system that falls below the scale of pH 7.0 (pH < 7).

Alkalinity: Alkalinity represents a high pH value usually greater than 7.0 and a strong alkaline soil having the pH value of 8.5 and above.

Analytical Grade: It is a high purity reagent or solute that are best suited for analytical applications. It is also called as analytical reagent.

Auto-oxidizing agent: A materials itself gets oxidized to transform to an oxidized form that degrades its own chemical composition.

Aggregate stability: Soil aggregate stability is a measure of the ability of soil aggregates to resist degradation when exposed to external forces such as water erosion and wind erosion, shrinking and swelling processes, and tillage.

Biochemical: It refers to the chemical processes and substances which occur within living organisms.

Buffer: It is a standard solution with a known pH value which are used to calibrate the pH meter in a laboratory.

Biodiversity: Biodiversity is a term used to describe the vast variety of life on Earth.

Biofertilizers: These are substances that contain living microorganisms generally applied to seeds, plant surfaces, or soils.

Bulk density: Bulk density is the weight of soil in a given volume.

Biochemical/Biological Oxygen Demand (BOD): It represents the amount of oxygen consumed by bacteria and other microorganisms while they decompose organic matter under aerobic conditions.

Contamination: It indicates undesirable substances or constituents that make the systems impure and risky in the course of action.

Calibration: Calibration is the process of configuring an instrument to provide a precise result for a sample within an acceptable range.

Carbon sequestration: It is the process of capturing and storing atmospheric carbon dioxide. It is one method of reducing carbon dioxide in the atmosphere to mitigate global climate change.

Cation exchange capacity: It is the total capacity of a soil to hold The exchangeable cations. CEC is an inherent soil characteristic and is difficult to alter significantly. It influences the soil's ability to hold onto essential nutrients and provides a buffer against soil acidification.

Chemical Oxygen Demand (COD): It measures the amount of oxygen consumed by reactions in a measured solution.

Contaminated water: Water containing undesirable physical, chemical, biological, or radiological , substances that is unfit for irrigation, drinking or domestic use.

Debris: Stones and large pieces of plant material, including roots, leaves etc.

Electrical conductivity (EC): It represents the ability of a material to conduct electric current. It refers to the measure of how electric current moves within a substance.

Equivalent weight: It is the mass of one equivalent of a given substance that will combine with or displace a fixed quantity of another substance.

Essential elements: Any mineral element that plays an important role in plant metabolisms and plant cannot complete its life cycle in its absence.

Ecosystem: A biological community of interacting organisms and their non-living environment.

Filtering and buffering: Buffering counteracts the acidification of the soil by means of the reaction of alkaline cations.

Filtration: mechanically filters solid substances out of percolated water. These dissolved substances are then bound primarily through sorption by humus and clay.

Good Laboratory Practices (GLPs): During soil and water testing, we need to follow standard procedures and techniques to get accurate soil and water samples analysis results. These standard techniques are termed as “Good Laboratory Practices”.

Gypsum requirement: The gypsum requirement (GR) is the calculated amount of gypsum necessary to apply to reclaim the alkali/sodic soil.

Hygroscopic chemicals: It is a chemical that absorbs moisture from the atmosphere to become moist.

Habitat: A habitat is a place where an organism makes its home.

Hazardous materials: Any substance or material that could adversely affect the safety of the public, handlers or carriers during transportation.

Hardness of water: The amount of dissolved calcium and magnesium in the water.

Interpretation: It refers to an act of explaining results. It is also known as inference.

Infiltration: Infiltration is the process by which water on the ground surface enters the soil.

Infected water: It refers to harmful microbial load mainly of pathogenic organisms present in it.or it is the amount of dissolved oxygen (DO) needed (i.e. demanded) by aerobic biological organisms to break down organic material present in a given water sample at a certain temperature over a specific period.

Maintenance: It is the process of preserving a condition or situation or the state of being preserved with a suitable procedure.

Molality (m): It is defined as the number of moles of solute per kilogram of solvent.

Molar Mass: It is defined as the mass in gm of 1 mole of the substance.

Molarity (M): It is the number of moles of solute or analyte in a litre of solution.

Mole fractions: The mole fraction or molar fraction is defined as the unit of the amount of a constituent (expressed in moles), divided by the total amount of all constituents in a mixture (also expressed in moles).

Molecular weight: Molecular weight is a measure of the sum of the atomic weight of the atoms in a molecule.

Macrofauna: Macrofauna organisms visible to the naked eye (> 0.5 mm), they can be found buried in sediment or attached to a fixed substrate (rocks, minerals, coral reefs etc.)

Macronutrients: Macronutrients are nutrients that are required in large quantities by all living things. For example, nitrogen, phosphorous, potassium, calcium etc.

Microfauna: Microfauna are the smallest of the soil fauna and are less than 0.1 mm in size, and so need a microscope to be seen e.g. Protozoa.

Micronutrients: The plant needs this element in a relatively smaller amount (≤100 mg/kg dry weight). The essential elements namely, Fe, Mn, Zn, Cu, Mo, Cl, Ni and B are known as micronutrients or trace elements or minor elements.

Normality (N): It is the number of 1 g equivalent weight of solute per litre of solution.

Nutrient cycling: In this process nutrients can be transformed into plant available forms, held in the soil, or even lost to air or water. It also refers the

movement and exchange of organic and inorganic matter back into the production of living matter.

Nutrient deficiency: It refers to a condition when the essential nutrients are not sufficiently supplied to meet the crops' requirement.

Nutrient holding capacity: It is the ability of soil to retain or hold the charged molecules or ions and mineral nutrients. The available nutrient content in the soil depends on the nutrient holding capacity of the soil.

Nutrient use efficiency: It refers to the ability of crops to take up and utilize nutrients for maximum yields.

Organic manures: It is the decomposed plant and animal matters used as plant nutrients to increase crop production. Manure provides most of the essential plant nutrients but in small quantities.

Parts per million (ppm): It is a way of expressing very dilute concentrations of substances and expressed as milligrams per liter or parts per million (mg/L or ppm) or micrograms per millilitre (µg/mL).

Percentage composition by volume: The concentration is expressed in terms of the solute and solvent volume.

Percentage composition by weight: The concentration is expressed in terms of the gram of solute per 100 g of solution.

Permissible limit: It is a limit or threshold value beyond which sudden impact or changes occurs in a system.

Precision: Precision expresses the degree of reproducibility or repeatability in an analysis.

Primary standard solution: A solution with a known mass of a primary standard and dissolved in a suitable solvent in a definite volume.

Primary standard: A primary standard is a reagent that is highly pure, stable, a consistent formula that does not change when exposed to the atmosphere, and has a high molecular weight.

Purity: It is the measurement of the amount of impurities found in a chemical sample.

Particulate organic matter: It is a fraction of total organic matter operationally defined as that which does not pass through a filter pore size that typically ranges in size from 0.053 and 2 mm.

Palatability: It refers to the quality of something of being great taste or acceptable in some other way.

Palatable water: Aesthetically pleasing and the presence of chemicals in it don't cause a threat to human health.

Permissible limit: It is a prescribed limit or guidelines above which its effects gives drastic impact on the systems.

Potable water: Safe to drink, pleasant to taste, and usable for domestic purposes.

Quality control: A system of maintaining standards in manufactured products/ soil and water testing by testing a sample of the output against the specification.

Quartering: The process of reducing a representative soil sample to a convenient size or of dividing a sample into two or more smaller samples for testing is called 'Quartering'.

Relief: The shape of the landscape is called relief or topography, influences soil formation, mainly through its effect on drainage and erosion, and partly through variations in exposure to the sun and wind and air drainage.

Representative sample: The sample represents the actual conditions of the study area from where it is collected.

Reagent: A reagent is a substance or compounds added to a system to start a chemical reaction or detect the presence or absence of another substance.

Reference materials: The material of various sources provides background information or quick facts on any given sample.

Radioactive substances: It is a substance that contains one or more radionuclides that are unstable and naturally release energy in the process of shedding high speed charged particles to reach their stable state.

Reference samples: The material of various sources provides background information or quick facts on any given sample.

Residual sodium carbonate (RSC): It is an index for assessing irrigation water to indicate the alkalinity hazard for soil.

Soil auger: It is a device used for soil sampling at different depths.

Soil concretion or Hardpan: A concretion is a hard, compact mass of matter formed by the precipitation of mineral cement within the spaces between particles.

Soil Fertility: It is the ability of a soil to supply essential plant nutrients for plant growth and agricultural production.

Soil health: It refers to the soil's capacity to perform different functions, e.g. nutrient cycling, buffering, filtering, biodiversity and crop production etc. It is also referred to as soil quality.

Soil permeability: Soil permeability is the property of the soil to transmit water and air.

Soil survey: Soil survey is a systematic examination and description of the soil of a particular area. It includes the classification and mapping of the properties and the distribution of various soil units.

Soil testing: Soil test is performed to quantify the different soil health indicators. Soil testing determines available nutrients (i.e. primary, secondary and micronutrients), soil organic carbon and pH. The basic idea behind soil testing is to recommend optimum quantity of fertilizers for plant growth and crop production.

Secondary standard solution: It is a solution with a known volume of secondary standards preparation in a definite volume.

Secondary standard: Secondary standard is a chemical that has been standardized against a primary standard for use in specific analysis in soil and water testing.

Solution: A solution is defined as a homogenous mixture of two or more substances.

Specific Gravity: It is the ratio of the density of a substance to the density of given reference material.

Standard Solution: Standard solution contains a known concentration or weight of an element or reagent, or substance in a definite volume of a solution.

Secondary Nutrients: These are the nutrients that plants require in smaller quantity than the macronutrients (nitrogen, phosphorus, and potassium). Plants need these nutrients in greater quantities than micronutrients. It includes Calcium (Ca), Magnesium (Mg) and Sulphur (S).

Soil aggregation: It is the arrangement and binding of primary soil particles (sand, silt and clay) in association with organic matter to form secondary units is called soil aggregation.

Soil compaction: Soil compaction is the reduction of soil volume due to external factors, this process adversely impacts soil productivity and soil health.

Soil enzymes: Soil enzymes increase the reaction rate at which plant residues decompose and release plant available nutrients. The substance acted upon by a soil enzyme is called the substrate. For example, glucosidase (soil enzyme) cleaves glucose from glucoside (substrate), a compound common in plants.

Soil Health Card: It is a card that contains information on the current status of soil health and, when used over time, to determine changes in soil health that are affected by land management.

Soil health indicator: Soil properties that can change rapidly in response to natural or anthropogenic actions are considered as good soil health indicators.

Soil health: It is defined as "the capacity of a living soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and promote plant and animal health".

Soil horizons: A soil horizon is a layer parallel to the soil surface whose physical, chemical and biological characteristics differ from the layers above and beneath.

Soil organic matter: It consists of plant and animal detritus at various stages of decomposition, cells and tissues of soil microbes, and substances that soil microbes synthesize.

Soil pH: It measures the soil acidity or alkalinity with relation to hydrogen ion (H^+) concentration. The pH scale goes from 0 to 14 with pH 7 as the neutral point.

Soil porosity: It is the amount of pores, or open space, between soil particles. Pore spaces may be formed due to the movement of roots, worms, and insects, expanding gases trapped within these spaces by groundwater, and/or the dissolution of the soil parent material.

Soil productivity: It is defined as soil capacity to support plant growth and produce a certain yield of crops using a defined set of management practices.

Soil Structure: The arrangement of the individual soil primary particles (sand, silt and clay) into large units is called 'soil structure'.

Surface sealing: Soil sealing crusts are soil platy surface layers which is often harden that are distinct from the rest of the bulk soil. It is also called the surface crust, which indicates poor infiltration, a problematical seedbed, and reduced air exchange between the soil and atmosphere.

Salt affected soil: Itis defined as soils with high concentrations of dissolved mineral salts in their profiles such that these dissolved salts adversely affect crop production.

Sodium Absorption Ratio (SAR): It is an indicator for assessing the suitability of water for use in agricultural irrigation, as determined from the concentrations of the main alkaline (Na^+) and earth alkaline cations (Ca^{2+} and Mg^{2+}) present in the water.

Soil strata: It refers to layers of soil within the soil profile.

Solubility: It is the ability of a solid, liquid, or gaseous chemical compound (solute) to dissolve in solvent (liquid).

Standards: It contains a known concentration or weight of an element or reagent, or substance in a definite volume.

Titration: It is the standard laboratory procedure used for quantitative chemical analysis for determining the concentration of identified analytes.

Toxic substances: It is a substance that adversely affect the health of living systems. It is also called as poisonous substances.

Turbidity: It indicates the cloudiness or haziness of liquid substances caused by large numbers of individual particles that are generally invisible to the naked eye, similar to smoke in the air. The measurement of turbidity is a crucial test for assessing water quality.

Valency: It is the ability of an atom to gain or lose electrons to achieve the noble gases like Helium (He), Neon (Ne), Argon (Ar), Krypton (Kr), Xenon (Xe) and Radon (Rn) electronic configuration.

Viscosity: Viscosity is a measure of a fluid's resistance to flow. It describes the internal friction of a moving fluid.

Water availability: The amount of water present in the soil profile and available for growing crops is called available water. Available water capacity is the amount of water stored in a soil profile and available for growing crops.

Water holding capacity: It refers to the amount of water that a given soil can hold.

Water relations: Soil can regulate the drainage, flow and storage of water and solutes, including nitrogen, phosphorus, pesticides, and other nutrients and compounds dissolved in the water. With proper functioning, soil partitions water for groundwater recharge and use by plants and animals.

Water quality: It measures suitable characteristics of water in terms of physical, chemical, and biological characteristics. It is useful to judge the suitability for irrigation, drinking or any other purpose.

List of Credits

Module-1:

Fig. 1.1: Dr. Somasundaram Jayaraman, *Principal Scientist*, ICAR-Indian Institute of Soil Science, Bhopal

Fig. 1.3: Dr. Nishant K Sinha, *Scientist*, ICAR-Indian Institute of Soil Science, Bhopal.

Fig. 1.4: Dr. Monoranjan Mohanty, *Principal Scientist*, ICAR-Indian Institute of Soil Science, Bhopal

Fig. 1.5: Dr. Monoranjan Mohanty, *Principal Scientist*, ICAR-Indian Institute of Soil Science, Bhopal

Fig. 1.6: Dr. Monoranjan Mohanty, *Principal Scientist*, ICAR-Indian Institute of Soil Science, Bhopal

Fig. 1.7: Analytical laboratory at ICAR- Indian Institute of Soil Sciences, Bhopal.

Fig. 1.8 (a-z): Soil and water testing laboratory at ICAR- Indian Institute of Soil Sciences, Bhopal.

Fig. 1.9(a-t): Soil and water testing laboratory at ICAR- Indian Institute of Soil Sciences, Bhopal.

Fig.1.10(a, b): Instrument room at ICAR-Indian Institute of Soil Science, Bhopal

Fig 1.11: https://tinyurl.com/jpzd7ztz

Module-3:

Fig. 3.6: http://soilhealth.dac.gov.in/

Fig. 3.7: http://soilhealth.dac.gov.in/

Fig. 3.8: http://soilhealth.dac.gov.in/

Fig. 3.9: http://soilhealth.dac.gov.in/