SOIL CHEMISTRY – COLOURS AND BONDING

Feedback form link & QR code:
https://ecolise.eu/curiosoil-lesson-plan-form-EN

Subject: Chemistry/Environmental Science/Arts
Duration: 45 minutes (can be much more if more time is allowed for discussions)
Age group: secondary school students (ages 14–16)
Topic: pH and nutrient availability/retention
Connection to Curiosoil tools: -

LEARNING OUTCOMES

Knowledge

- Recall that different soils and materials (e.g., leaves, ash, conifer needles, water) have characteristic pH values.
- Understand that soil pH influences nutrient availability, cation exchange, and even heavy metal bioavailability.
- Compare the reliability of different testing methods (pH meter, vinegar/baking soda) and recognize their limitations for scientific accuracy

Skills

- Accurately use simple and field-based tools (pH meter, test strips, vinegar/baking soda) to measure soil pH.
- Handle soil and materials safely, following lab/field safety regulations.
- Observe and interpret reactions (colour changes, fizzing) and estimate acidity/alkalinity.
- Record and organize results in a clear table, including peer comparison data.
- Communicate findings in group discussions using scientific vocabulary (acidic, alkaline, neutral, reliable, limitation).

Competences

- Demonstrate the ability to evaluate testing methods for their reliability and practical use in soil science and agriculture.
- Work effectively in a collaborative group setting, sharing tasks and contributing observations.
- Reflect critically on the relationship between soil chemistry and ecosystem services, such as food production and pollution buffering.

LEARNING OBJECTIVES ALIGNED WITH SOIL COMPETENCE AREAS

1. Soil functions

Indicators: Students can explain links between soil chemistry and plant growth.
Descriptors: Students demonstrate understanding that soils are dynamic systems regulating nutrient availability through chemical and physical properties.

2. Soil diversity
Indicators: Students record contrasting pH values across soils/materials and explain why sandy soils lose nutrients faster than clayey soils.
Descriptors: Students recognise that soils are diverse ecosystems with variable properties that affect how they function and support life.

3. Soil threats
Indicators: Students understand why some soils may be degraded or leached; models include “unattached” nutrients when sites are full; group discussion highlights threats like overfertilization or acidification.
Descriptors: Students understand that soil chemistry is vulnerable to human pressures, leading to nutrient imbalance, pollution, or loss of soil fertility.

4. Soil solutions
Indicators: Students propose solutions during wrap-up; models show organic matter increasing nutrient binding; group presentations connect findings to real soil management.
Descriptors: Demonstrates awareness of strategies to prevent, mitigate, or restore soil degradation by monitoring pH and enhancing soil’s nutrient-holding capacity.

LESSON STRUCTURE

Activity 1: Testing soil pH with different methods
Duration: 20 minutes

Description
Students test soil and other components (eggshells, ash, sawdust, leaves, conifer needles, water) using three methods to compare (i) the pH of different soils and materials that are connected to soil and (ii) reliability.

Materials
- Different soils (from several locations, could also be brought to class by students) and component samples in labeled containers
- Field pH meter (if available)
- Vinegar and baking soda
- Beakers/containers with lids

Setup instructions
- Remind students about safety regulations.
- Prepare samples and distribute into group trays

Step-by-step process
1. As an introduction, the teacher explains the experiment or shows a short video.
2. Students split into small groups. Each group receives a tray with either soil or other material.
3. Test each sample with (a) field pH meter and (b) vinegar/baking soda.
   (a) Place a little bit of soil in the tray and add a few droplets of indicator solution. Slightly move the tray to mix soil and indicator solution.

Wait a few moments for a reaction of the indicator solution.
Read the pH value from the scale according to the resulting color.

(b) Put soil in a container and add vinegar or baking soda as explained in the video.

Note: 10% HCl which is usually used in soil science for testing for carbonates in the field will lead to stronger reactions than vinegar.

4. Students observe the reaction of the indicator solution/vinegar/baking soda and note down their experience with an estimation of a weak/strong/no reaction.
5. Students compare values/reactions between different soils and materials (either with the whole class or by asking fellow groups in a peer-to-peer setting).

Recording

Students observe the reaction of the indicator solution/vinegar/baking soda and note down their experience with an estimation of a weak/strong/no reaction.
Students note down their own experiments' results as well as at least results from two other materials.

Group discussion (selection of possible guiding questions):

1. Comparing soils and materials
- Which soils or materials were most acidic? Which were most alkaline?
- Did the results match what you expected based on the material (e.g., conifer needles vs. ash)? Why or why not?
2. Method reliability
- Which testing method (pH meter vs. vinegar/baking soda) gave the clearest or most reliable results?
- What were the limitations of each method? How might this affect real soil testing in science or agriculture?
3. Connections to soil chemistry and plants
- How might soil pH affect the ability of plants to take up nutrients?
- Why do you think farmers, gardeners, or foresters care about soil pH?
- How could soil pH influence the presence of heavy metals or toxic elements?
4. Critical thinking & real-world application
- What could people do if their soil is too acidic or too alkaline for the plants they want to grow?
- How might human activities (e.g., adding fertilizers, burning wood, acid rain) change soil pH over time?

Activity 2: Modeling nutrient bonding with soil minerals

Duration: 25 minutes

Description

Students explore how soil texture and cation exchange capacity affect nutrient retention by building hands-on models of nutrients attaching to mineral surfaces. Working in small groups, they use simple materials (e.g., Lego, clay, beads) to represent minerals, nutrient ions, and organic matter, following rules that mimic real soil processes.

Materials
- Soil (clayey and sandy)
- Materials for building models (Lego, clay, beads, paper, etc.)
- Printed set of rules for modelling
- PC, beamer, sound system (for display of video)

Setup instructions
Prepare a small amount of soil of contrasting textures and enough materials for building models in small groups.

Step-by-step process

1. The teacher explains that soil fertility is influenced not only by the amount of nutrients present, but also by:
   - **Soil texture** (the proportion of sand, silt, and clay), which affects the surface area available for nutrient attachment.
   - **Cation Exchange Capacity (CEC)**, which determines how well soils can retain and exchange nutrient ions.

   To illustrate this, the teacher shows:
   - Samples of sandy soil and clayey soil for students to touch and compare.
   - Macroscopic or microscopic images of mineral particles (e.g., clay minerals).
   - An optional short video that visualizes how nutrients interact with soil surfaces.

2. As a whole class, students briefly discuss:
   - Why sandy soil tends to lose nutrients quickly.
   - Why clay and organic matter can hold onto nutrients more effectively.
   - How this influences plant growth and environmental impacts (e.g., nutrient leaching).

3. Students work in small groups (4–5 students) to build models showing how nutrients attach to mineral surfaces.
   - Materials: Lego bricks, plasticine/clay, beads, pipe cleaners, paper cutouts, or other simple modeling materials (teacher- or student-provided).
   - Each group decides how to represent:
     - Mineral particles (e.g., clay plates, sand grains).
     - Nutrient ions (positively or negatively charged).
     - Organic matter (humus) if included as part of the binding system (optional).

<u>Possible rules for modelling:</u>
- **Mineral surface:** Clearly represent at least one mineral particle (sand or clay). Clay surfaces should have more “attachment points” than sand.
- **Charge representation:** Nutrient ions must be shown with their charge (e.g., + for cations like Ca^{2+}, K^{+}, NH_4^{+}; - for anions like NO_3^{-}, PO_4^{3-}).
- **Bonding:** Nutrient ions can only attach to mineral surfaces at specific binding sites. Each site can hold one nutrient ion at a time.
- **Competition:** If more nutrient ions are added than there are binding sites, some must remain “in solution” (unattached).

- **Organic matter interaction:** Groups may add organic matter to demonstrate how it increases binding sites and improves nutrient retention.
- **Flexibility:** Groups can redesign their models if they realize improvements along the way, but they must be able to explain their choices.

4. Wrap up: Each group briefly presents their model, explaining:
    - How nutrients are bound to the soil particles.
    - Why some soils retain nutrients better than others.
    - How their model connects to real soil processes (fertilization, leaching, plant uptake).

Recording
Students build models and write down their ideas for the wrap-up discussion.

Assessment

Formative assessment (during the activities)
- Teacher observes group collaboration, accuracy in following procedures, and safe handling of materials.
- Students' notes/tables on pH results and carbonate reactions are checked for completeness and clarity.
- Teacher asks probing questions during model building (e.g., "Why did you add more attachment points to the clay particle?").
- Quick thumbs-up/thumbs-down checks or mini whiteboard responses: *"Would sandy soil hold more or fewer nutrients than clay soil? Why?"*

Summative assessment (end of the lesson/short follow-up)
- Short written reflection or quiz:
    - Explain how soil pH influences nutrient uptake.
    - Compare nutrient retention in sandy vs. clay soils.
- Group presentation of models assessed with a simple rubric: clarity, accuracy, explanation of real-world link

Differentiation strategies

For advanced learners
- Provide additional primary source documents about pH, nutrient solubility, and nutrient-mineral interactions
- Extension research on heavy metal pollution

For struggling learners
- Provide step-by-step worksheets with visuals (e.g. table for recording observations)
- Pair with supportive peers for group work
- Offer guiding questions during the activity: "What do you notice about the colour change? What does that tell you about acidity?"

For students whose first language is not the language of instruction
- Use visuals, diagrams, and symbols for charge (+/-) and binding sites.
- Provide bilingual vocabulary cards with key terms (acidic, alkaline, nutrient, binding, clay, sand)
- Allow collaboration with bilingual peers
- Allow non-verbal participation in model building, with verbal support from peers.

Extension activities

Immediate extensions
- If available, test also with a pH meter that shows the pH value in numbers (some devices are put directly in the soil, some require soil to dissolve in deionised water).
- Soils may be tested for nutrient availability using test strips (e.g. ammonium, nitrate, phosphate) which can usually be purchased in pharmacies
- Research local soils: let students bring soil from home/garden/park and analyse differences

Home learning
- Choose household materials to test pH for the next lesson (e.g. lemon juice, soap)
- Draw a poster showing “How nutrients stick to soil minerals”

Health and safety considerations
- Ensure soil samples are safe for handling
- Provide hand sanitizer after soil observation activity
- Monitor group dynamics during debate activities to ensure respectful discourse

Syllabus content reference
This lesson addresses:
- Soil pH and its relation to nutrients
- Nutrient retention via mineral surfaces

Teacher's preparation notes

Printing instructions
Set of rules for modelling
Preparation of materials for pH testing and modelling