Soil Colour as Physics — Teacher's Guide

Earth Pigments from the Soils of Müllrose

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Earth Pigments from the Soils of Müllrose

Erdpuls Müllrose — Living Laboratory & Makerspace Garden

Part of the "Brücken bauen durch Boden — 13 Questions to the Soil" project

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Purpose of This Guide

This Teacher's Guide accompanies three differentiated lesson-plan documents (Classes 1–4, Classes 5–8, and Classes 9–12) and the accompanying Pedagogical Framework. It provides everything you need to deliver the Soil Colour as Physics unit confidently: subject-matter preparation, safety guidance, materials management, assessment approaches, and logistical support for the Erdpuls campus visits.

You do not need to be a physics or chemistry specialist to deliver this unit. The "Body first, then instrument" principle that runs through all grade levels means that your students' hands, eyes, and questions do most of the teaching. Your role is to hold the space for discovery, ask good follow-up questions, and connect what students notice to the concepts in this guide.

How This Unit Fits the Erdpuls Project

The "Brücken bauen durch Boden" project asks **104 questions to farmers** across three partner farms (conventional, organic, biodynamic). Each of the 13 questions receives one painted answer per farmer — that is 104 paintings, all made with earth pigments produced from local Müllrose soils.

Students in this unit do not produce samples. They produce the actual pigment medium for a real artwork that will travel. This is the difference between a school exercise and genuine participation in a project. Keep that in mind throughout: the work matters beyond the classroom.

The three farms give students something rare — a direct, side-by-side comparison of how a farmer's relationship with the land shows up in the colour of the soil itself. That is both a scientific question and a human one.

Subject-Matter Preparation

The Core Physics in Plain Language

Why does soil have colour?

Soil colour comes primarily from iron. Iron makes up about 5% of the Earth's crust and exists in soils in several mineral forms, each with a different colour. The key ones in the Müllrose region are:

- **Goethite** (iron oxyhydroxide): yellow to yellow-brown. This is the most common iron mineral in Brandenburg soils.
- **Lepidocrocite**: orange-red. Forms where iron is alternately wet and dry.
- **Haematite** (iron oxide): red to red-brown. Dominates in warmer-climate soils; can form here where soil has been disturbed or heated.
- **Ferrihydrite**: freshly precipitated, red-orange. Often seen near springs or drainage channels.
- **Organic matter (humus)**: dark brown to black. More organic matter = darker soil. Biodynamically managed farms in this project typically show more humus.
- **Quartz**: white to pale grey. The sandy soils of the Oder-Spree region are rich in quartz.

Why does colour change with wetness?

Dry soil has air in its pores. Light bouncing off many air-mineral interfaces scatters strongly in all directions — this is called Mie scattering — and makes the soil appear lighter. When water fills those pores, there are fewer interfaces, less scattering, and the soil looks darker. This can be observed and measured by students at every grade level.

Why does grinding change the colour?

Smaller particles have more surface area per unit of mass. More surface = more light interaction. Finely ground iron oxide pigments appear richer and more saturated in colour than coarsely ground versions of the same soil. But grind too fine (below about 5 μm), and the pigment becomes semi-transparent — covering power actually drops again.

Why does earth paint lighten as it dries?

As the water or oil binder evaporates, the pigment particles gradually become surrounded by air rather than liquid. Air has a lower refractive index than binder materials. The result: more Mie scattering at the surfaces, which lightens the appearance. The same physical mechanism as the wet-dry effect in the field.

The Key Minerals at a Glance

Mineral	Formula	Colour	Where found locally
Goethite	α-FeOOH	Yellow–yellow-brown	Agricultural brown earths
Lepidocrocite	γ-FeOOH	Orange-red	Gley soils near lakes and streams
Haematite	α-Fe_2O_3	Red–red-brown	Podzol ortstein layer
Ferrihydrite	$Fe_5O_8H \cdot 4H_2O$	Red-orange	Near drainage channels
Humus	Organic compounds	Dark brown–black	Fen soils, biodynamic farm fields
Quartz	SiO_2	White–pale grey	Sandy raw soils, sandpits

Connections to Curriculum Areas

Grade band	Primary curriculum area	Secondary connections
1–4	Science (Sachunterricht)	Art, Geography
5–8	Physics, Biology	Art, Geography, Chemistry
9–10	Physics, Chemistry	Mathematics, Biology
11–12	Physics, Chemistry	Mathematics, Ecology, Research methods

Safety Guidelines

This unit involves working with soil, fine dust, and simple chemical binders. All activities are safe when the following protocols are followed.

Dust Safety (All Grade Levels)

Fine quartz dust (particles below 10 μm) is a lung hazard with prolonged repeated exposure — this is the cause of silicosis in miners and quarry workers. In a school context with occasional grinding sessions the actual risk is very low, but precautionary practice is required:

- **FFP2 dust masks** must be worn during all dry grinding and sieving.
- **Safety goggles** must be worn during grinding.

- **Good ventilation** is required — open windows or work outdoors during dry processing.
- Wet-route processing (stirring soil into water) eliminates the dust risk entirely and is the preferred method for younger students (Classes 1–4 and 5–8).

Binder Safety

- **Linseed oil**: Non-toxic. Rags soaked in linseed oil can ignite spontaneously — spread flat to dry, never ball up.
- **Gum arabic**: Non-toxic, water-soluble.
- **Egg yolk (tempera)**: Standard food item. Perishable — do not store prepared paint for more than a few days.
- **Casein (from quark)**: Non-toxic.
- All binders are safe for students at all grade levels.

Soil Handling

- Wash hands after all soil handling.
- Do not eat or drink in the workspace.
- Soils from partner farms are agricultural soils with no unusual contamination. Use site description sheets to confirm this before collecting.

For Classes 1–4 Specifically

- Wet route only — no dry grinding or sieving.
- Pre-sieved soil samples from the teacher (remove stones and debris before class).
- Supervision ratio of at least 1:8 during hands-on activities.

Materials Management

Before the Unit

1. Contact the Erdpuls team to confirm your visit dates and which partner farms will be included in the sampling.
2. Request the site description form and Munsell chart reference (or simplified photographic version) from the project documentation.
3. Review the sample collection map in Section 2.3 of the concept document to identify your sampling sites.
4. Pre-dry soil samples at 50°C for 24 hours if preparing lab materials in advance (do NOT exceed 50°C — goethite converts to haematite above 250°C, changing the colour permanently).

Consumables Checklist (per class group)

Item	Quantity needed	Notes
Pre-collected soil samples (min. 3 sites)	200–500 g each	Dry at 50°C beforehand
FFP2 dust masks	1 per student	Required for dry grinding
Safety goggles	1 per student	Required for grinding
Mortar and pestle (porcelain)	2–4	Wash between samples
Sieves: 500/250/100/63 µm	1 set	For grades 5–12 only
Digital balance (1 mg)	1	For grades 5–12 only
Watercolour paper 300 g/m²	3 sheets per student	Heavier paper holds pigment better
Linseed oil	100 ml	
Gum arabic (10% solution)	100 ml	Mix 10 g in 100 ml warm water
Egg yolks	4–6	Fresh on the day
Small glass jars (50 ml)	10–15	For storing pigment batches
Water in containers	—	For wet processing
Paintbrushes (flat, 10–20 mm)	1 per student	Flat brushes work best
Disposable gloves	1 pair per student	Optional but useful

Digital Tools (Free)

- **Spectroid** (iOS / Android): Reflection spectroscopy app for smartphone
- **GIMP**: Image editing for RGB colour analysis (desktop)
- **Physics Toolbox Sensor Suite**: Alternative spectroscopy approach
- **RRUFF Project** (rruff.info): Reference spectra for mineral identification
- **SoilGrids** (soilgrids.org): Online soil maps for regional comparison

The 4A-Pathway in Your Lessons

Every lesson sequence at Erdpuls follows the **4A-Pathway**: Awareness → Acknowledgment → Attitude → Action. You do not need to announce this structure to students — it is a teacher's map, not a student handout.

Stage	What it looks like in your lesson
Awareness	Students encounter soil and colour directly, in the field or with samples in hand, before any explanation is given. "What do you notice? What surprises you?"
Acknowledgment	Students measure, compare, and see that their sensory impression is confirmed by data. "The wetter sample really is darker — and here is the measurement to prove it."
Attitude	Students form their own view of the connection between farming practice and soil colour. This is not a fact to memorise — it is a question to hold.
Action	Students produce real pigments for the Erdpuls WP4 exhibition. Their work enters the world.

Make sure every unit, even a single 45-minute session, has a moment from each stage. The Action stage does not require actual pigment production — it can be as simple as: "What would you do with this colour if you were making a painting about the soil you collected it from?"

Assessment Guidance

This unit is primarily assessed through **process documentation** rather than written tests. Suggested approaches:

All Grade Levels — Soil Colour Journal

Students keep a running journal of their samples, observations, and questions. This functions as both a learning tool and an assessment artifact. Prompts to include: - A colour swatch from each soil sample (painted or photographed) - Three observations in words - One question the sample raises

Classes 5–8 — Lab Report (Light)

A simple one-page document: what did we do, what did we measure, what do we notice? Focus on the wet–dry experiment and the binder comparison as the core data to record.

Classes 9–12 — Research Report or Presentation

Students design and conduct their own mini-investigation (see the Classes 9–12 lesson plan) and present findings. Assessment criteria: clarity of research question, quality of measurement, interpretation of data, connection to the broader project thesis.

Self-Assessment Question (All Levels)

At the end of the unit, ask: *"What does this soil's colour tell you about its history?"* The quality of a student's answer to this question is a good proxy for depth of understanding across all grade levels.

Frequently Asked Questions

What if we can't visit the partner farms? Pre-collected samples from the farms can be provided by the Erdpuls team. Contact Michel Garand at the project office. The field-visit lessons can be adapted to work with sample kits brought to the classroom.

What if students have no prior knowledge of optics or chemistry? The unit is designed to build from direct sensory experience. No prior knowledge is required. The concept document's Section 3 (Physical Principles) provides the background you need — you can introduce as much or as little as your class is ready for.

The wet-dry experiment — how wet should the sample be? Fully saturated (dripping). The contrast with the completely dry version is what makes the effect clearly visible. Use the same sample mass (5–10 g) for both states.

Can we use soils from our school garden instead of the farm sites? Yes, for most experiments. The three-farm comparison is the most educationally powerful aspect of this unit, but local school garden soil works well for the grinding, spectroscopy, and binder experiments.

How do we store finished pigments? In tightly sealed glass jars, away from light. Dry earth pigments store indefinitely. Mixed paints (with egg yolk or gum arabic) should be used within a week or refrigerated.

Connecting to the Exhibition

The finished pigments from your class join the **Müllrose Earth Colour Library** — the material source for the 104 exhibition paintings. If possible:

1. Label each jar with the site name, date, farm, depth, and your class name.
2. Photograph the jar against a white background for the colour library record.
3. Share the photograph with the Erdpuls project office for inclusion in the project archive.

Students who see their labelled jar on the table in the exhibition room have a different relationship to the finished artwork than any other audience member. That is worth the extra five minutes of labelling.

Further Reading

- Schwertmann, U. & Cornell, R.M. (2000): *Iron Oxides in the Laboratory.* Wiley-VCH. [Schwertmann was Professor at TU München — the definitive European reference on iron oxide mineralogy and soil colour]
- Blume, H.-P. et al. (2018): *Scheffer/Schachtschabel: Lehrbuch der Bodenkunde.* 17th ed. Springer Spektrum. [The standard German soil science textbook; covers iron oxide colour, humus, and soil formation in depth. English edition: *Soil Science,* Springer 2016]
- AG Boden / BGR (2024): *Bodenkundliche Kartieranleitung* (KA6). 6th ed. E. Schweizerbart, Stuttgart. [The official German field guide for soil description, sampling, and classification — essential background for the fieldwork units. In German]
- Doerner, M. / Hoppe, T. (2011): *Malmaterial und seine Verwendung im Bilde.* 24th ed. Maier, Ravensburg. [Classic German reference on painting materials, pigments, and binders; covers earth pigments and binder chemistry in detail. In German]
- Delamare, F. & Guineau, B. (2000): *Colour: Making and Using Dyes and Pigments.* Thames & Hudson. [French authors; accessible introduction to the science and history of pigments]
- Canti, M. (2003): Earthen pigments and their analysis. *English Heritage Research Transactions.*
- **Toland, A., Noller, J.S. & Wessolek, G.** (Eds.) (2019): *Field to Palette — Dialogues on Soil and Art in the Anthropocene.* CRC Press / Taylor & Francis. 681 pp. [The central reference for the science-art bridge this unit is built on. Over 100 contributors including soil scientists, artists, and educators; includes DIY experiments and soil recipes. Wessolek is Emeritus at TU Berlin — the direct institutional neighbour of the Erdpuls project]
- **Feller, C., Landa, E.R., Toland, A. & Wessolek, G.** (2015): Case studies of soil in art. *SOIL* 1: 543–559. DOI: 10.5194/soil-1-543-2015 [Open access; shorter and classroom-accessible; covers earth pigments and soil art across cultures and history. Freely downloadable]
- **Wessolek, G.** (2021): Böden in Kunst und Gesellschaft neu positionieren. *Handbuch der Bodenkunde.* Wiley. DOI: 10.1002/9783527678495.hbbk2021001 [In German; theoretical grounding of soil science's role in public education and society — direct BNE relevance]
- **Public Lab** (publiclab.org/wiki/spectrometry): DIY spectrometer build instructions [Note: SpectralWorkbench.org closed in August 2022; for classroom spectroscopy use the Spectroid app listed in the Digital Tools section above]

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