Short guide to circular soil chromatography

Workshop edition

Introduction

Soil is an extremely complex substance: minerals, water, air, organic material, and a multitude of living beings come together to create a dynamic self-regulating system. Often ignored and poorly understood, soil is crucial to the survival of our civilization. Beyond being the foundation for growing food, it regulates water cycles, sustains biodiversity, and stabilizes the climate. In this booklet, we explore how to use circular chromatography as an engaging tool for education on the topic of soils.

Circular chromatography is a method of analysis that was developed in the mid-20th century and is still used by "biodynamic" farmers all over the world. In this technique, liquids travel through filter paper, drawn by capillary forces. The individual components of a soil extract move faster or slower, according to their size and physical/chemical properties. The filter papers are soaked with a very diluted solution of silver nitrate, which is known for its extreme sensitivity to light. The soil components that are being separated by the filter paper create specific patterns and when they react with silver nitrate, some of them also develop vibrant colors.

Similar substances share similar characteristic patterns and colors, which means that the chromatograms of degraded soils can look very similar to each other, but are usually very different from rich organic soils or composts. Over the last decades, some efforts have been made to quantify and objectify the results of soil chromatography, with interesting results (see further reading), but the main strength of circular chromatography may lie precisely in its subjective nature.

Circular chromatography as an educational tool

A good workshop brings people together and creates a relaxed environment for hands-on learning, exchange, and discussion. Circular chromatography is simple enough to be performed with groups of teenagers or adults, while at the same time touching upon various interesting topics from chemistry and physics to biology, art, and philosophy. It can be viewed as a scientific method, a technique for artistic exploration, and in some ways even as a spiritual endeavor. The history of its adaptation as a tool for biodynamic soil analysis allows us not only to discuss important questions regarding soil fertility but also reflect on different modes of thinking.

By examining soil samples from various locations, participants can learn about the factors that impact soil health, such as agriculture, pollution, and land management practices. Depending on the location and context of the workshop, this experience offers various opportunities for reflection: degraded landscapes, community gardens, and city parks provide a wide variety of soil types and ecosystems that can be compared with each other; on a farm, the soils of different crop systems, manures or composts can be analyzed.

The development of the chromatograms (“chromas”) is an astonishing process full of surprises, even for experienced practitioners. Each chroma is unique, as it reflects not only the sample from which it is derived but also to some degree the environmental conditions (temperature, humidity, microbial activity, etc.) and an individual signature of the experimenter. In the days after their creation, the color patterns of the chromas will undergo significant changes, encouraging participants to remain engaged long after the workshop. Back at home, the chromas are often prominently displayed and have the potential to spark conversations about soil in much wider social circles.

Possible topics to address during the workshop

Soil health & land management

Healthy soil is the basis of our civilization. Industrialized agriculture leads to a loss of soil structure, nutrient degradation, and contamination – ultimately breaking down ecosystems and eroding the soil to infertile desert. There is no universal recipe for soil regeneration, since every garden, farm, or forest has its unique conditions. Making Earth a better place to live requires observation, lots of time, and mindful interaction.

"Classic" soil science

Soil types, composition, chemical and physical properties, minerals, microbial ecosystems, etc. – all of these characteristics are in one way or the other expressed in the chromas, although it is sometimes very difficult to correlate them to a specific color pattern or shape. There are many books, videos, podcasts, etc. about soil science, but good information about circular chromatography is not so easy to find.

Natural sciences

Making a soil extract with a sodium-hydroxide solution (NaOH) and the reaction of the compounds with silver-nitrate ($AgNO_3$) are primarily chemical processes. Chromatography itself is a physical process that relies on capillary forces to transport liquids, dissolved minerals, and organic material through the filter paper. The soil itself originates from intertwined biological, chemical, and physical processes that often unfold over the course of thousands or even millions of years.

History of circular chromatography

Early forms of chromatography were developed in the 19th century. In the 1950s, Ehrenfried Pfeiffer adapted the method to analyze soil samples in the context of anthroposophic ("biodynamic") agriculture. Anthroposophy is a controversial spiritual philosophy founded by Rudolf Steiner in the early 20th century. It extends into practical applications such as agriculture, education (Waldorf), alternative medicine, art, and many other fields.

Workshop structure

For a fulfilling experience with circular soil chromatography, it is necessary to devote some time to it. Although the actual hands-on work is straightforward and quick, many steps involve waiting. With a 2-day format, the participants will be able to experience the complete process, from taking the soil samples to the finished chromas.

Depending on the group, venue, and context of the workshop, it can also be a good idea to ask the participanats to bring their own samples and encourage them to share the specific history of their soil and why they chose it.

DAY 1	**~ 3–4 h**
10 min	Introduction
20 min	Taking samples
60 min	Drying samples → **Gap #1**
30 min	Making soil extracts
	Preparing solutions, filter papers & wicks
30 min	Soaking filters in $AgNO_3$ (darkroom)
	Mixing soil extracts → **Gap #2**
End	Letting filter papers dry (darkroom)
	Moving soil extracts to the darkroom

DAY 2	**~ 3–4 h**
30 min	Starting the chromatography (small groups, darkroom)
60 min	Chromatography (darkroom) → **Gap #3**
30 min	Drying the chromas (darkroom) → **Gap #4**
60 min	Developing & discussing the chromas

Tools

- scale (at least 0.1 g precision, if you have $AgNO_3$ as a solid)
- measuring glass (~50–100 ml)
- glass jars or plastic tubes (minimum 50 ml) → one per sample
- petri dishes, lids of jars, or something similar → one per sample
- 1 l jar/glass for the NaOH solution (or 2 x 500 ml)
- ~100 ml jar/tube for the $AgNO_3$ solution
- small kitchen sieves
- pipettes (~2–10 ml)
- rubber gloves
- scissors
- red light (if the darkroom is very dark)
- string and clothes pegs (for drying chromas)
- spoons/ small shovels (for taking samples)

Materials (for 20 chromas)

- silver nitrate ($AgNO_3$) → 0.2 g
- sodium hydroxide (NaOH) → 10 g
- distilled water → ~1.5 l
- 22 filter papers (15 cm diameter) ↘

Two of them will be used for the "wicks" (see step 3). We had good experiences with retention rates of 5-8 µm, but others may work fine as well.

Requirements for the space

In the main workshop area, each participant needs some space on a stable table to process their soil sample(s). The darkroom can be improvised with cardboard, blankets, etc. – the darker the better. A little indirect light is OK and red lamps can be used. For each chroma, an even and flat surface (table/ shelf/ board) of at least 15 x 15 cm is needed, plus some extra for the samples, etc.

To process 20 chromas, we need a minimum table size of 150 x 50 cm.

The workshop

DAY 1

Introduction

- welcome the participants and explain the concept of the workshop
  keep it very short, there is more time later

Taking & drying samples

- encourage the participants to connect with their surroundings and choose an area or a plant that attracts them → we suggest 1–3 samples per participant, depending on the available space in the darkroom
- for a sensory experience, the samples can be collected with bare hands
  ~20 g each
- spread the soil on some cardboard or newspaper in the shade
  it is also possible to use a food dehydrator to speed up the process
- one participant who finishes early can prepare the 1% NaOH solution
  50 ml per sample – 10 g NaOH in 1 l distilled water is enough for 20 chromas

Gap #1

- early in the workshop, it makes sense to address the topics of soil health, land management, and “classic” soil science
- a great interactive approach is to arrange the soil samples according to their color, humidity, clay/sand ratio, or other criteria on a large piece of paper
  the participants can evaluate their sample themselves and say a few words about it
- encourage a sensory approach to the soil: feel, smell, and maybe even taste

Making soil extracts

- sieve 5 g of dry soil (~1–2 mm holes) & mix with 50 ml 1% NaOH
- gently shake or stir the solution several times in the next 1–2 hours

If the sample is rich in organic matter, it will take longer to settle. Ideally, the sedimentation happens in your darkroom, so you don't have to move the samples again when doing the chromatography.

Preparing the material

- one participant who finishes making their soil extracts early can prepare the silver nitrate solution (in the darkroom)

→ → Use gloves and minimize light exposure when handling $AgNO_3$!!! ← ←

0.5% $AgNO_3$ solution

e.g. 0.5 g $AgNO_3$ in 100 ml of distilled water

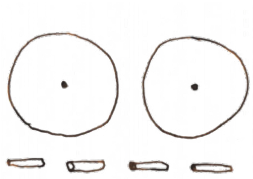
you will need 2 ml per chroma,
so this would be enough for about 50 chromas
you can store the solution in a light-proof bottle (use aluminum foil to improvise)

- Another participant can prepare the filter papers & wicks

make a hole in the middle of each filter paper (~3–5 mm)

for the wicks, cut a filter paper into squares (~2x2 cm) and roll them into cylinders

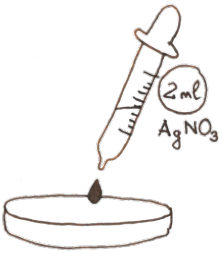
make twice as many wicks as there are filters (you will need them later)



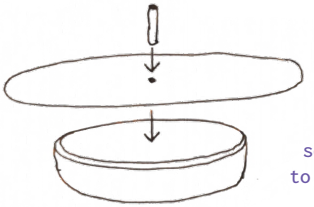
Soaking the filter papers with $AgNO_3$

❋ with gloves and in the darkroom

depending on the size of the group and darkroom, this can be done by a small team or successively in pairs →



pipette 2 ml of $AgNO_3$ solution onto the petridish / jar cap

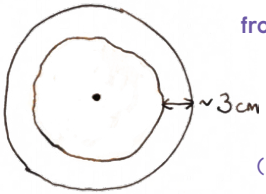


insert a wick into the hole of the filter paper and place it onto the dish

make sure the wick touches the solution – it will immediately start to soak into the filter paper

repeat this process for all filter papers

you can do all of them inparallel – depending on the paper it will take 5–20 min to soak



when the solution reaches ~5 cm from the edge, remove the wick and let the filter papers dry

you can leave the filter papers on the petri dish, place them on cardboard, or hang them from a string (in the dark!)

Drying the filter papers & stirring the soil extracts

- filter papers treated with $AgNO_3$ should be kept in the dark at all times – when continuing the next day, we suggest storing them in a closed box
- the soil extracts are gently stirred every ~30 min until the end of the first day of the workshop
  If you want to compare the results, the intervals, the overall extraction time, and the sedimentation should be the same in all samples
- the samples can sediment overnight in the darkroom and should be moved as little as possible the next day

Gap #2

- at this point of the workshop, it makes sense to talk about the chemistry and physics of the chromatography process
- this can also be combined with a glimpse into the history of circular chromatography (depending on time and motivation)

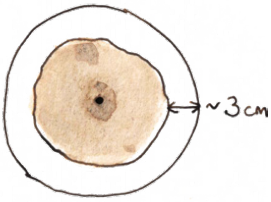
DAY 2

Soaking the filter paper with your soil extracts

❋ with gloves and in the darkroom

- mark the edge of each filter paper with your name and a clear identifier of the sample
- clean the petri dishes / jar lids and use fresh wicks
- pipette 2 ml of the supernatant (liquid above the sedimented soil) from the jar into the petri dish
- repeat the same process as for soaking with $AgNO_3$
- stop the chromatography when the solution reaches ~2–3 cm from the edge or when the image does not change anymore

  depending on your sample and paper, this can take up to 1 hour



Troubleshooting

- if the solution travels less than ~1/2 the distance to the edge, consider using a higher dilution for your next experiments and/or a longer sedimentation time
- if all chromas appear pale and without clear patterns, try a higher concentration of soil (e.g. 10 g)

Gap #3

- check on the chromas every ~10 min and stop the ones that are getting near to the edge (remove the wick and let them dry)
- if any of them look stagnant, check if the wick is still submerged in the extract
- during this gap, the group could visit the sampling locations and every participant could say a few words about why they chose theirs

  if there is enough time, this can also happen at the very end of the workshop when you can take along the developed chromas

- it's also nice to draw a large-scale map of the area and later place the chromas according to their location

Drying & developing the chromas

- let your chromas dry in the darkroom (e.g. hanging on a string)
- when dry, they can be touched without gloves and should be exposed to indirect sunlight for a few hours to develop their colors

Gap #4 / End .....

- this gap usually merges with gap #3, so the activities can be continued while the chromas are drying
- before giving any input about the interpretation, it can be very interesting to ask the participants what they see and how they feel about their chromas
  (this can also happen in groups of 2-3 people)
- give a short introduction about the typical features of the chromas (zones, channels and spikes) and point out good examples
- let the participants compare their chromas, reflect on the sample locations, and gather ideas for future explorations

Of course, it is often expected of the workshop facilitator to explain what the patterns and colors reveal about the soil quality. Depending on your level of experience, it is great to share some insights, but don't turn it into a lecture.

Interpretation & evaluation

Circular chromatography follows a strict protocol and yields highly reproducible results, but the interpretation of the chromas remains largely inaccessible to scientific analysis. Although comparative studies successfully correlated some visual aspects of the chromatograms with (bio) chemical properties of the soil (further reading), an accurate blueprint for a science-based interpretation did not emerge. For the use of the method as an educational tool, this might be considered an advantage, since it renders the images more intriguing. It also opens a discussion about the limitations of trying to reduce a complex substance like soil to mere numbers. What is more interesting: an Excel sheet or a vibrant image?

A chromatogram is created by the chemical and physical composition of the soil and by the billions of microorganisms that inhabit it. The patterns and colors directly emerge from a living system – we can only assist in their manifestation and development. Within the framework of biodynamic agriculture, circular chromatography is not only considered a reliable method for analyzing soil composition, but the chromas are also interpreted in regard to the *energetic* properties of the soil. Please contact your local biodynamic farming association if you would like to learn more about this approach. On the following pages, we will share the results of some of our experiments, but we will not dive deep into the art of *reading* a soil chroma.

People with great experience have standardized the interpretation by separating the chroma into concentric rings (*zones*) and radial features (*channels* and *spikes*). The presence and colors of those zones and their relation to the radial features can give us clues about certain properties of the soil. Dark brown colors – especially in the outer zones – are usually a sign of the presence of organic matter, while channels suggest microbial activity. It is considered an indication of high fertility if the channels reach all the way from the center of the chroma to its edge. Yellow, gray and other colors can indicate the presence of certain minerals, but sometimes also severe degradation or contamination. Soils with low fertility often show clearly separated zone boundaries and their channels (if present) don’t reach into the center of the chroma.

Examples

High fertility

The chromas represent very different soils used for growing various crops. The samples G) and H) are from Slovenia, while I) is from Mendoza, Argentina.

Features: High variation in colors and patterns; Differently shaped, but clear channels in samples G) and H), but not in sample I).

A) Garden

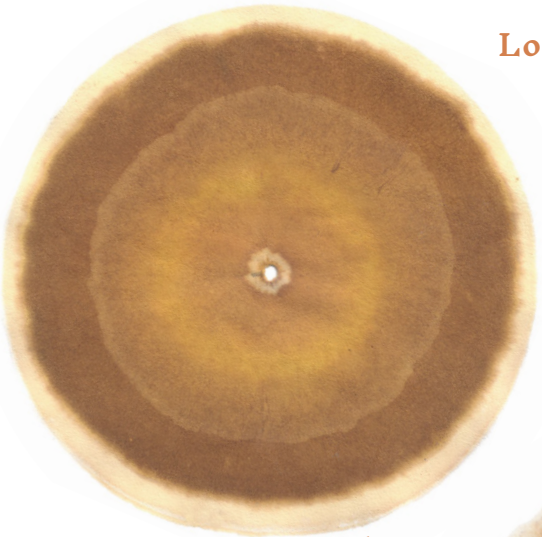
B) Forest

C) Graveyard

Low fertility

The 3 chromas represent samples with very low amounts of organic matter.

Features: Yellow tone in the internal zone (all 3); No channels or spikes in sample D); Jagged radial features in samples E) and F); Darker reddish brown tone and channels reaching into the outer zone in sample F).



D) Masonry sand

E) Sandy river sediment

F) Sandy soil

Agricultural soils

The chromas represent very different soils used for growing various crops. The samples G) and H) are from Slovenia, while I) is from Mendoza, Argentina.

Features: High variation in colors and patterns; Differently shaped, but clear channels in samples G) and H), but not in sample I).

G) Vegetable patch

H) Potato field

I) Vineyard

Urban soils

The chromas represent 3 different samples from a workshop in the center of Ljubljana. Sample J) is from the edge of a construction pit containing clay and gravel; Sample K) is from a wetland on top of an underground garage; Sample L) is from a clay deposit that is also being used for pottery.

Features: Clear zone borders J) and K); Brown color in the central zone and prominent channels (all samples); Grey middle zone in samples J) and K); Pronounced spikes in sample J); Dark brown external zone in sample K).

J) Construction pit

K) On top of garage

L) Natural clay deposit

Notes

Further readings

Pfeiffer (1959) **"The Art and Science of Composting"** Biodynamics #49 and **"Qualitative chromatographic method for the determination of biological factors"** Biodynamics #50

Hassild-Piezunka (2003) **"Eignung des Chroma-Boden-Tests zur Bestimmung von Kompostqualität und Rottegrad"** PhD thesis, University Oldenburg

Brinton (2010) **"Assessing Compost & Humus Condition by Circular Chromatography"** Journal of the woods end research Lab Vol 1:1

Restrepo, Pinheiro (2011) **"Cromatografía - Imágenes de vida y destrucción del suelo"** Book published by Impresora Feriva (only in Spanish)

Kokornaczyk, Primavera, Luneia, Baumgartner, Betti (2016) **"Analysis of soils by means of Pfeiffer's circular chromatography test and comparison to chemical analysis results"** Biological Agriculture & Horticulture

Ford, Cook, Tunbridge, Tilbrook (2019) **"Using paper chromatography for assessing soil health in southwestern Australia"** Centre of Excellence in Natural Resource Management, University of Western Australia

Graciano, Matsumoto (2020) **"Evaluating Pfeiffer Chromatography for Its Validation as an Indicator of Soil Quality"** Journal of Agricultural Studies

Ford, Stewart, Tunbridge, Tilbrook (2021) **"Paper chromatography: An inconsistent tool for assessing soil health"** Geoderma, Volume 383

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Links

(1) mikrobiomik.org
(2) archive.org
(3) projekt-atol.si
(4) krater.si
(5) rewildingcultures.net

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