



DIY ELECTRONICS / DIY ELEKTRONIKA

LABBOOK

Electricity from mud / Elektrika iz blata

DO-IT-YOURSELF / NAREDI SAM



LABBOOK

Electricity from mud: build your own microbial fuel cell / Elektriika iz blata: naredi si gorivno celico iz mikrobov

DIY electronics.1 / DIY elektronika.1

Author / Avtor: Dr. Julian Chollet (mikroBIOMIK)

This labbook from mikroBIOMIK shows you how to harvest the power of soil bacteria to produce electricity. / Priročnik, ki ga držiš v roki, je skupek navodil, kako si lahko zgradiš svojo gorivno celico iz blata in z njo napajaš preproste elektronske naprave.

Levels of difficulty / Stopnje težavnosti

1. AN INQUIRING MIND / RADOVEDNEŽ

Suitable for anyone / Primerno za vsakogar

2. RESEARCHER / RAZISKOVALEC

I'm not familiar with the field, but I'll manage with a bit of effort / Ne poznam področja, ampak bom zmožen z malo razmišljanja

3. EXPERT / POZNAVALEC

I have enough knowledge to work independently / Imam dovolj znanja za samostojno delo

4. MASTER / MOJSTER

I'm quite skilled and possess an in-depth understanding of the tricks of the artistic and scientific trades / Sem kar vešč, vstopam v polje poglobljenega razumevanja umetniških in znanstvenih trikov

5. DEVELOPER / RAZVIJALEC

I have sufficient knowledge to be capable of guiding those from categories 1–3 / Znam že toliko, da lahko vodim druge iz kategorij 1–3

6. MENTOR / MENTOR

I understand the content, I've mastered the technology, I develop new knowledge independently and pass it on to others / Razumem vsebine, obvladam tehnologije, samostojno razvijam in posredujem znanja



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Introduction / Uvod

The Microbial Fuel Cell / Mikrobna gorivna celica

Soil-based microbial fuel cells convert chemical energy derived from bacterial metabolism into electrical energy that can be measured and used to power low-voltage devices. Electrogenic (“electricity-generating”) bacteria can be found in almost all terrestrial and aquatic ecosystems, where they perform key functions in organic matter degradation, nutrient cycling and biofilm formation. Their abundance in the sediments of lakes, ponds and wetlands is an important factor in the ability of wetlands to sequester and store atmospheric carbon. / Mikrobne gorivne celice na osnovi prsti pretvarjajo kemično energijo bakterijskega metabolizma v električno energijo, ki jo je mogoče izmeriti oziroma uporabiti za napajanje nizkonapetostnih naprav. Elektrogene bakterije (torej takšne, ki proizvajajo električno energijo) najdemo v skoraj vseh kopnih in vodnih ekosistemi, kjer imajo ključno vlogo pri razkrajanju organskih snovi, kroženju hranil in tvorjenju biofilmov. Njihova visoka zastopanost v sedimentih jezer, ribnikov in mokrišč pomembno prispeva k sposobnosti mokrišč za vezavo in shranjevanje atmosferskega ogljika.

Microbial fuel cells have started to find commercial use in wastewater treatment and as biosensors for measuring organic-matter content or biochemical oxygen demand. Their potential for powering low-voltage devices is currently being explored for specialized applications such as environmental monitoring. / Mikrobne gorivne celice se začnajo uporabljati v komercialne namene za čiščenje odpadnih voda ter kot biosenzorji za merjenje vsebnosti organskih snovi ali biokemijske potrebe po kisiku. Njihova potencialna raba za napajanje nizkonapetostnih naprav se trenutno raziskuje za uporabo na specializiranih področjih, na primer pri spremljanju stanja okolja.

How it Works / Princip delovanja

Microbial fuel cells are not to be confused with “lemon” or “potato” batteries, which rely on the oxidation of metals like zinc or magnesium. Here, the fruit or vegetable provides a solvent (electrolyte) and the term “battery” fits very well because the metal is dissolved in the process. Much like in commercial Ni/Ca or lead batteries, this process is purely electrochemical. / Mikrobni gorivni celici ne smemo zamenjevati s tako imenovanimi »limoninimi« ali »krompirjevimi« baterijami, ki delujejo na osnovi oksidacije kovin, kot sta cink ali magnezij. Pri takšni bateriji sadje oz. zelenjava zgolj zagotavlja topilo (elektrolit); poimenovanje »baterija« je torej zelo primerno, saj v njej pride do raztapljanja kovine. Ta proces je, tako kot v komercialnih nikelj-kadmijevih ali svinčenih baterijah, povsem elektrokemične narave.

In soil-based microbial fuel cells, the electricity is generated by bacteria that degrade organic material. The underlying principle is biological, though the productivity of the microbes and therefore their power output is very much influenced by the chemical and physical conditions in the mud and the design of the electrodes. / V mikrobni gorivni celici na osnovi prsti električno energijo proizvajajo bakterije, ki razkrajajo organski material. Osnovni princip je biološki, pri čemer na produktivnost mikrobov, s tem pa tudi na njihovo proizvodnjo energije, vplivajo kemične in fizikalne razmere v blatu ter zasnova elektrod.

The Workshop / Delavnica

Building a soil-based microbial fuel cell allows the integration of multiple scientific disciplines (microbiology, chemistry, electronics, etc.) with an artistic DIY approach to technology. The basic principle of microbial fuel cells has been successfully used for citizen-science projects, conventional school education and art and design purposes. For our workshops, we mostly use recycled and readily available materials to build small-scale devices that the participants can take home for further observation. The design of the fuel-cells is reduced to the basic necessities and functions very reliably, even several months (or years) after the workshop. /

Izdelava gorivne celice iz prsti združuje več znanstvenih disciplin (mikrobiologija, kemija, elektronika itd.) ter umetniški, naredi-sam pristop k tehnologiji. Osnovni princip mikrobnih gorivnih celic je bil uspešno uporabljen v projektih ljubiteljske znanosti, konvencionalnem šolskem procesu, pa tudi na področju umetnosti in oblikovanja. Na delavnicah uporabljamo pretežno reciklirane in zlahka dostopne materiale, iz katerih gradimo majhne naprave, ki jih lahko udeleženci odnesejo domov za nadaljnje opazovanje. Zasnovo gorivne celice smo oklestili na najosnovnejše komponente in njeno delovanje je zelo zanesljivo še več mesecev (in celo let) po delavnici.

Tools / Orodje

1. shovel / lopata
2. bucket / vedro
3. small pliers / male klešče
4. multimeter

Material / Material

1. container(s) - e.g. a glass jar with a lid / steklen kozarec za vlaganje s pokrovčkom
2. wires (copper or steel - ideally recycled) / žica – jeklena ali bakrena
3. pencils or graphite sticks / svinčnik ali grafitna ploščica
4. duck tape / lepilni trak

The Basic Design / Preprosta zasnova

1. For the first prototype, we use the most simple design in order to understand the principle. / Za prvi prototip bomo uporabili zelo preprosto zasnovo gorivne celice in se tako seznanili z njenim delovanjem.
2. The initial power output will be low, but it will increase over the next few days and should then be stable for months or even years. / Na začetku bo blatna gorivna celica proizvajala zelo malo energije, ki pa bo z vsakim dodatnim dnevom rasla. Gorivna celica iz blata lahko zdrži tudi več mesecev oziroma celo let.



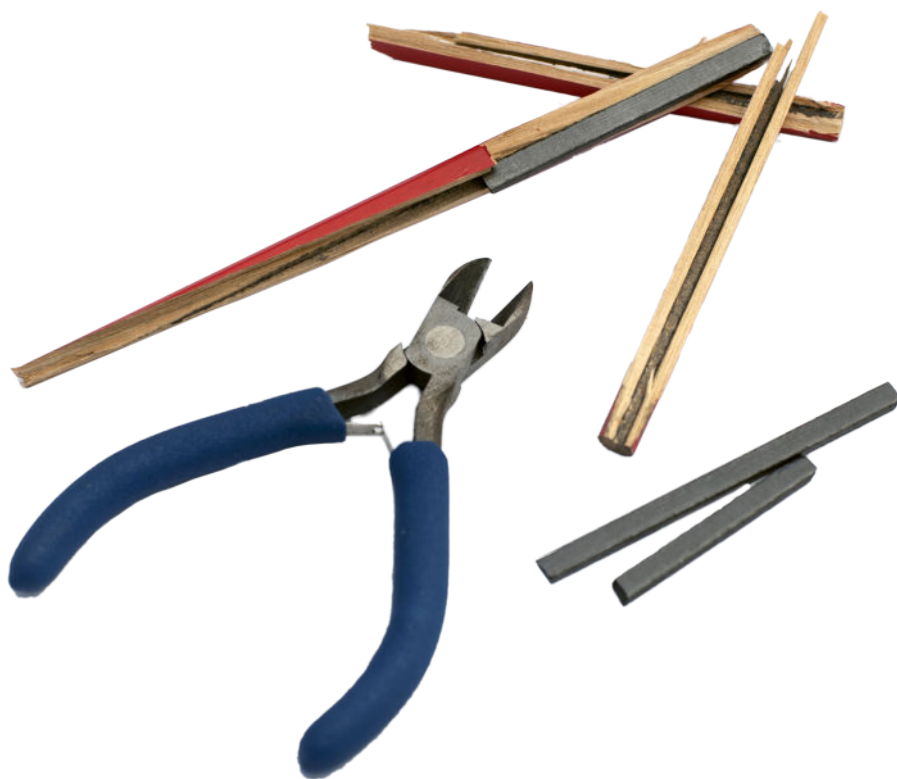
STEP 1: Collect some mud / KORAK 1: Nabiranje blata

1. Explore the surroundings and search for some mud (e.g. the sediments in ponds, rivers and swamps). / Razišči bližnjo okolico in poišči blato (npr. usedline iz jezer, ribnikov, rek ali močvirja).
2. Fill about 1 litre into a bucket and bring it to the experimentation table. / Naberite in shranite približno 1 l blata.
3. The mud should be dark brown, dark grey or black and should have the consistency of yoghurt or honey (add or remove water if needed). / Blato mora biti temno rjave, temno sive ali črne barve in imeti primerno gostoto – nekje med jogurtom in medom. Za ustrezno gostoto lahko dodate vodo.

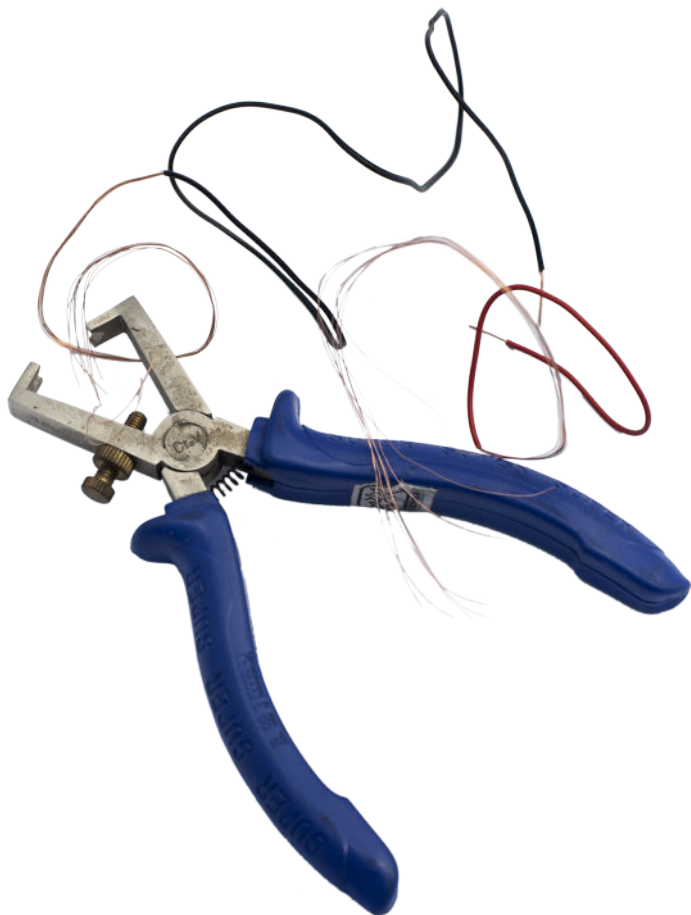


STEP 2: Build carbon electrodes / KORAK 2: **Sestavi elektrodi iz ogljika**

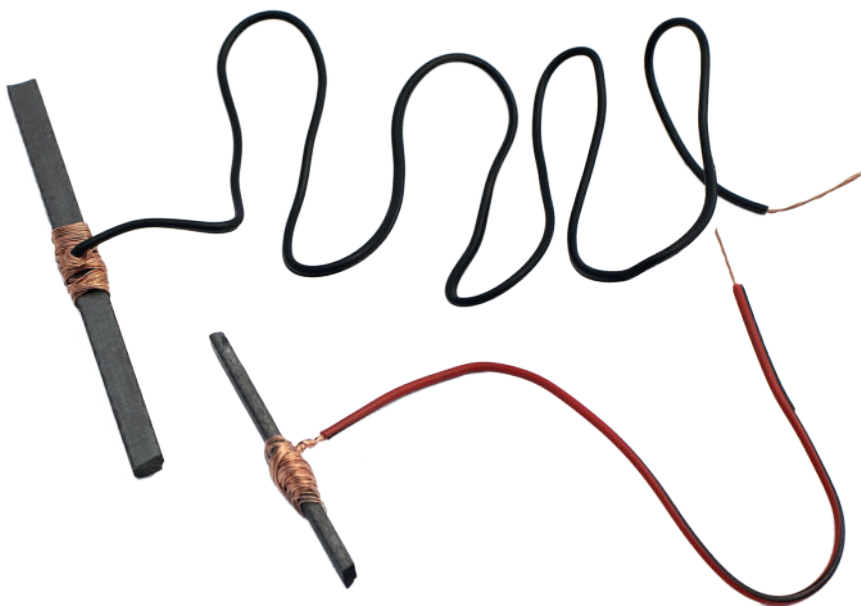
1. Both electrodes should be of the same material to avoid reduction and oxidation effects. / Obe elektrodi morata biti iz istega materiala – tako preprečimo reakciji oksidacije in redukcije.
2. The graphite from pencils works well; charcoal for drawing and even coal from the fire is suitable. / Elektrode lahko naredimo iz grafitne ploščice ali pa iz grafita v svinčniku, uporabimo lahko tudi risarsko oglje ali premog.



3. Great carbon-electrodes can also be recycled from old electric motors (carbon “brushes”). / Dobre ogljikove elektrode je mogoče reciklirati tudi iz starih električnih motorjev (ogljikove »ščetke«).
4. You will need 2 wires (ideally black and red) - the black one should be about 30 cm long, the red one can be 15-20 cm. / Potrebuješ dve žici različnih barv (idealno rdeče in črne) – črna žica naj bo dolga prib. 30 cm, rdeča pa med 15 in 20 cm.



5. Strip off the insulation at both ends of the wires - one end about 10 cm, the other 1-2 cm. / Na obeh straneh žic odstrani izolacijo – na eni strani 10 cm in na drugi 1–2 cm.
6. Wind the wire tightly around the graphite until it is firmly attached. / Žico trdno zavij okrog grafita, da je trdno pritrjena in se ne bo snela.



If you use two different metals as electrodes, it is likely that one will be oxidized (rust), which can also create an electric current, but only until the metal is completely rusted. / Če za elektrode uporabljaš dve različni kovini, bo verjetno ena oksidirala (rja), kar lahko povzroči tudi produkcijo električnega toka – vendar le toliko časa, dokler kovina popolnoma ne zarjavi.

STEP 3: Place the anode and fill the jar / **KORAK 3: V kozarec položi anodo in ga** **napolni z blatom**

1. Place one electrode (the anode / negative electrode) on the bottom of the jar - if you used black and red cables, this should be the electrode with the black cable. / Položi negativno elektrodo (anodo) na dno kozarca – če si uporabil/a črno in rdečo žico, je to elektroda s črno žico.



3. Gently fill the jar with mud - the mud should be very wet (if it does not drip into the jar by itself, mix in some water). / Previdno napolni kozarec z blatom. Blato mora biti zelo mokro – praktično mora kapljati v kozarec (če ne kaplja, dodaj vodo).
4. Make sure that there are no larger air bubbles in the mud. Use a stick to squeeze them out if necessary. / V blatu ne sme biti večjih zračnih mehurčkov. Če se vseeno pojavijo, uporabi palico in jih iztisni.
5. The jar should be filled to 1-2 cm below the rim. / Kozarec mora biti napolnjen 1–2 cm od vrhnjega roba.

STEP 4: Carefully place the upper electrode / **KORAK 4: Previdno dodaj še drugo elektrodo**

1. The upper electrode is supposed to be only partially submerged in the mud because it has to be in contact with the air. / Elektroda na vrhu kozarca mora biti samo delno potopljena v blato, saj mora ostati v stiku z zrakom.



2. Be careful when closing the lid and check from the side that it is still placed correctly. / Bodi zelo previden/na, ko zapiraš kozarec – opazuj, če je elektroda še vedno na pravem mestu.
3. To close the lid, it might be necessary to bend the metal or make holes for the cables to pass through. / Da boš lahko zaprl/a kozarec, v pokrovček z izvijačem naredi luknjo, skozi katero potegneš obe žici, ali pa upogni rob pokrovčka.
4. Consider using some duct tape to hold the cables (and lid) in the right position. / Z lepilnim trakom lahko žico in pokrovček pričvrstiš na želeno mesto.

STEP 5: Make the first measurements / **KORAK 5: Opravi prve meritve**

1. Switch your multimeter to direct current voltage (e.g. “DCV” depending on your device. / Na multimetru izberi funkcijo DCV oziroma V–, s katero lahko merimo enosmerno napetost (npr. v baterijah).



2. The lower electrode is the negative (-) pole (anode) and the upper electrode is the positive (+) pole (cathode). / Spodnja elektroda je negativni pol (anoda), zgornja pa pozitivni pol (katoda).
3. The initial power output will be low, but it will increase over the next few days - so continue measuring your fuel cell after the workshop! / Na začetku bo izhodna moč gorivne celice majhna, a se bo v naslednjih dneh povečala, zato lahko meritve izvajate tudi po končani delavnici!
4. Voltages below 50 mV are absolutely normal in the first few hours and even negative voltage can sometimes occur. After 1 or 2 days, the voltage should be between 300 and 600 mV. / Normalno je, da je v prvih urah izdelave napetost gorivne celice pod 50 mV, pade lahko celo pod nič – torej se lahko pojavi tudi negativna napetost. Po 1–2 dneh bo napetost narasla na 300–600 mV.

Troubleshooting / Odpravljanje težav

Very low or negative voltage / Zelo nizka ali negativna napetost

1. As mentioned above, low voltages are normal in the first few hours after building the fuel-cell. / Kot smo omenili že v prejšnjem poglavju, je nizka napetost na začetku normalna.
2. If the voltage remains low or drops over time, a gentle pull on the red wire may get the fuel cell going again (make sure you fix the cable in the new position, for example with a strip of duct tape). / Če je napetost po nekaj dneh še vedno zelo nizka oziroma njena vrednost čez čas pade, lahko z nežnim potegom oz. premikom rdeče žice začne ponovno delovati. Žice ne pozabi ponovno pritrditi z lepilnim trakom!

A layer of water is forming on top of the mud / Na vrhu kozarca se nabira voda

1. This is not necessarily a problem, as long as the cathode is still in contact with the air. / Če je katoda v stiku z zrakom, to ni problematično.
2. For transport, it is better to remove the water to avoid spilling and dislocation of the electrodes. You can simply open the jar and gently pour out the excess water or skim it off with a spoon. / Če boš napravo premikal/a, je vodo bolje odstraniti in se s tem izogniti polivanju ali premikanju elektrod. Vodo lahko preprosto odliješ ali pa uporabiš žlico.

A drop of voltage or inversion of the poles / Padec napetosti ali inverzija

1. Make sure the upper electrode has sufficient air contact (see “very low or negative voltage”) - during transport especially, the electrode can be displaced! / Preveri, ali je vrhnja elektroda v stiku z zrakom (več o tem v poglavju Zelo nizka ali negativna napetost) – hitro se lahko zgodi, sploh če kozarec premikamo, da se elektroda prestavi.
2. If you have been using the fuel cell to power a device (calculator, small LED, etc.), try disconnecting it for a while and see if the voltage increases again. / Če gorivno celico uporabljaš za napajanje elektronske narave (npr. žepnega kalkulatorja ali ledice), jo za nekaj časa odklopi in preveri, ali se napetost dvigne.
3. If your fuel cell is several months old (or if the mud had a low organic content), it is possible that the microbes don't have enough food anymore – try mixing in some decomposing leaves, small pieces of non-coated cardboard or other organic material. / Možno je, sploh če je gorivna celica stara več mesecev (možno je tudi, da je blato vsebovalo malo organskih snovi), da je mikrobom pošla hrana – v kozarec vmešaj razpadajoče listje, majhne koščke neprevlečenega kartona ali katerikoli drug organski material.

Measurement Table / Tabela meritev

	Date / Datum	Output power (mV/V) / Izhodna moč v voltih (mV/ V)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		



About mikroBIOMIK / O mikroBIOMIK

The mikroBIOMIK Society is a non-profit association for the promotion of intrinsic curiosity and participation in science, with a strong focus on invisible creatures. It is an interdisciplinary network of scientists, physicians, ecologists, teachers, artists and other curious people exploring various strategies for disseminating knowledge and experience. / mikroBIOMIK je neprofitna organizacija, ki spodbuja raziskovanje v znanosti, z močnim poudarkom na nevidnih bitjih. Dr. Julian Chollet je nomadski znanstvenik s področja molekularne biologije in član iniciative HUMUS Sapiens. www.mikrobiomik.org

Credits / Kolofon

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Production / Produkcija

konS platform

Projekt Atol Institute

PIFcamp



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UMETNOST

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