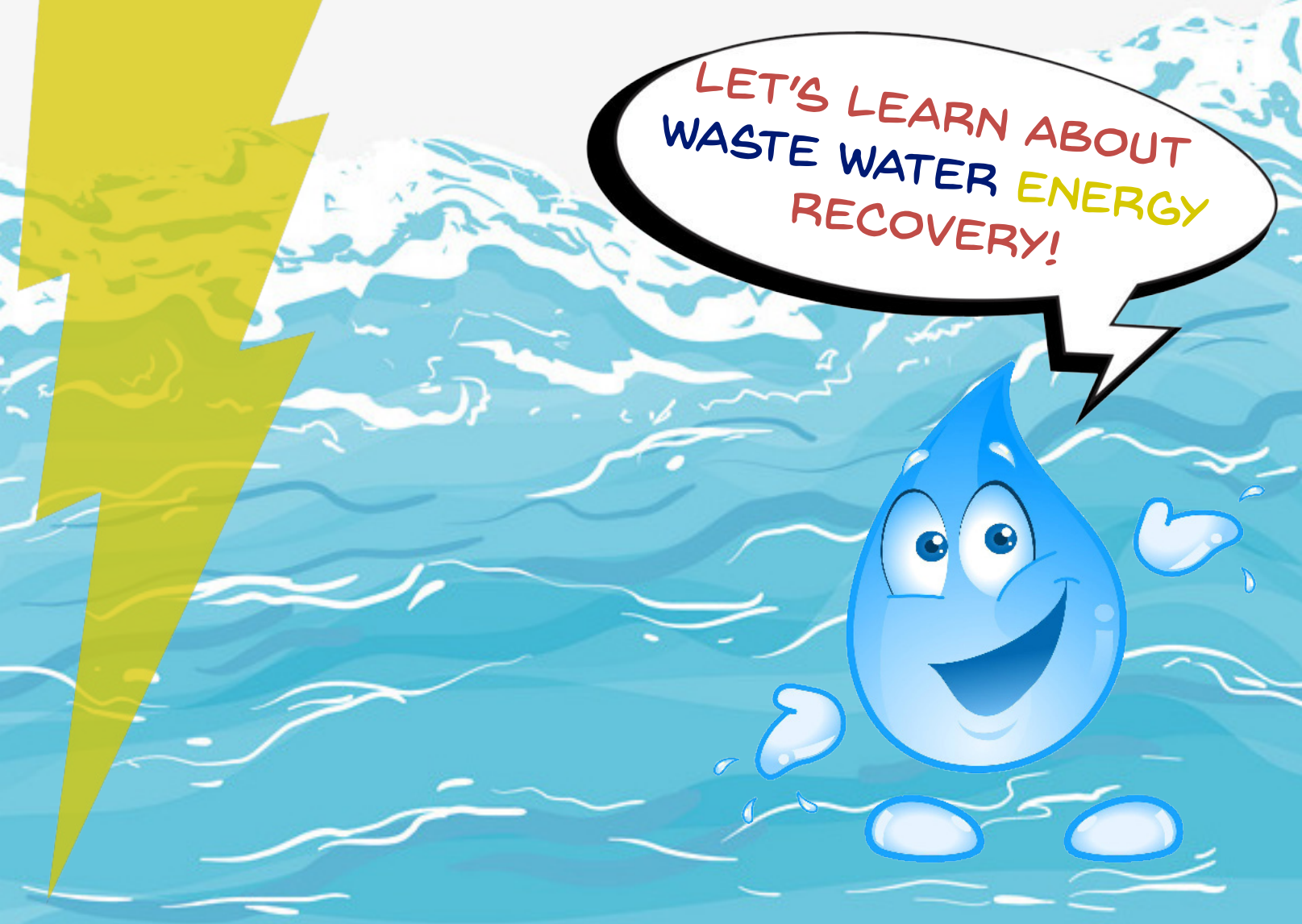
LET'S LEARN ABOUT
WASTE WATER ENERGY
RECOVERY!

Credits

Content: Juan Esteban Ramírez
Design, layout and translation: Daniël Wiersma, Pamela Cerón
Technical review and field implementation: Larissa Terumi, Marco Hartl
Technical review: Philipp Kerin, Hermine Verschueren

Disclaimer

Enginyeria Sense Fronteres

MARIE CURIE ACTIONS

Belgium
partner in development

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CONTENT

INTRODUCTION

Water is a very important resource on our planet. If we imagine our lives without enough and clean water, the picture doesn't look pretty, right? Fortunately, each of us can contribute to improving the water situation in our community. The problem is not going to be solved from night to morning, but if we start summing efforts, we are going to see changes in our current reality. We need to improve our drinking water consumption and protect our water resources. On the other hand, we need to learn about wastewater treatment and why it's important and interesting (believe it or not). The last one is becoming more interesting, due to the new sustainability focus. In recent years, besides providing a clean effluent, we want to recover "stuff" from wastewater. And how cool, that we are even able to get energy out of it.

With this booklet, we want to guide you through getting some understanding of water conservation, wastewater treatment and resource recovery. And of course, we want to have fun building with our own hands a microbial fuel cell.

Ok, too many words for now, let's get started!!!

1. PREVIOUS ACTIVITY:

Goals of the human knot game

- With this game, you can boost your cooperation and improve your team building skills
- Problem-solving through the generation of positive emotions while you can get to know others better

Get a lot of fun and be sure to bring a pile of laughs during the activity

What do we need?

- Total Time: 20-30 minutes
  - 5 minutes to set up
  - 10-20 minutes to solve the knot
  - 5 minutes to review and discuss
- 8 to 12 participants ideally
- Space Required: Small. Indoors or outdoors

How to play The Human Knot Game?

a) Choose a player on your team. This player has the aim to be a facilitator, helping and leading the solving process.

b) All the players need to stand in a circle, close together with your shoulders almost touching.

c) Close your eyes and lift both hands, reaching across to take the hand of someone standing across the circle.

d) The facilitator needs to be sure that no one grabs the hand of the person right next to the players.

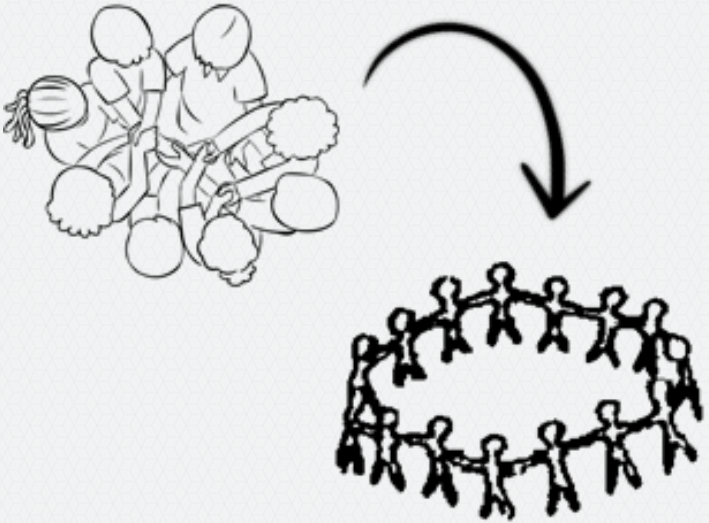
e) Now, the fun begins!! Open your eyes and work together to untangle the human knot without letting go of any hands. The goal is to end up in a perfect circle again. The facilitator will help the team giving instructions mediating to find the best solution.

f) You can go over or under each other's arms, or through legs if needed! Be careful! Don't break the chain in the process.

LET'S WORK AS A TEAM! WE CAN SOLVE THE HUMAN KNOT!

Learning outcomes:

- How did you feel during the experience? Did you use a strategy to solve the puzzle?
- Which role had the facilitator during the process? Did the facilitator behave as a leader?
- Discuss the different roles of the players and propose new solutions.



2. UNDERSTANDING CONCEPTS:

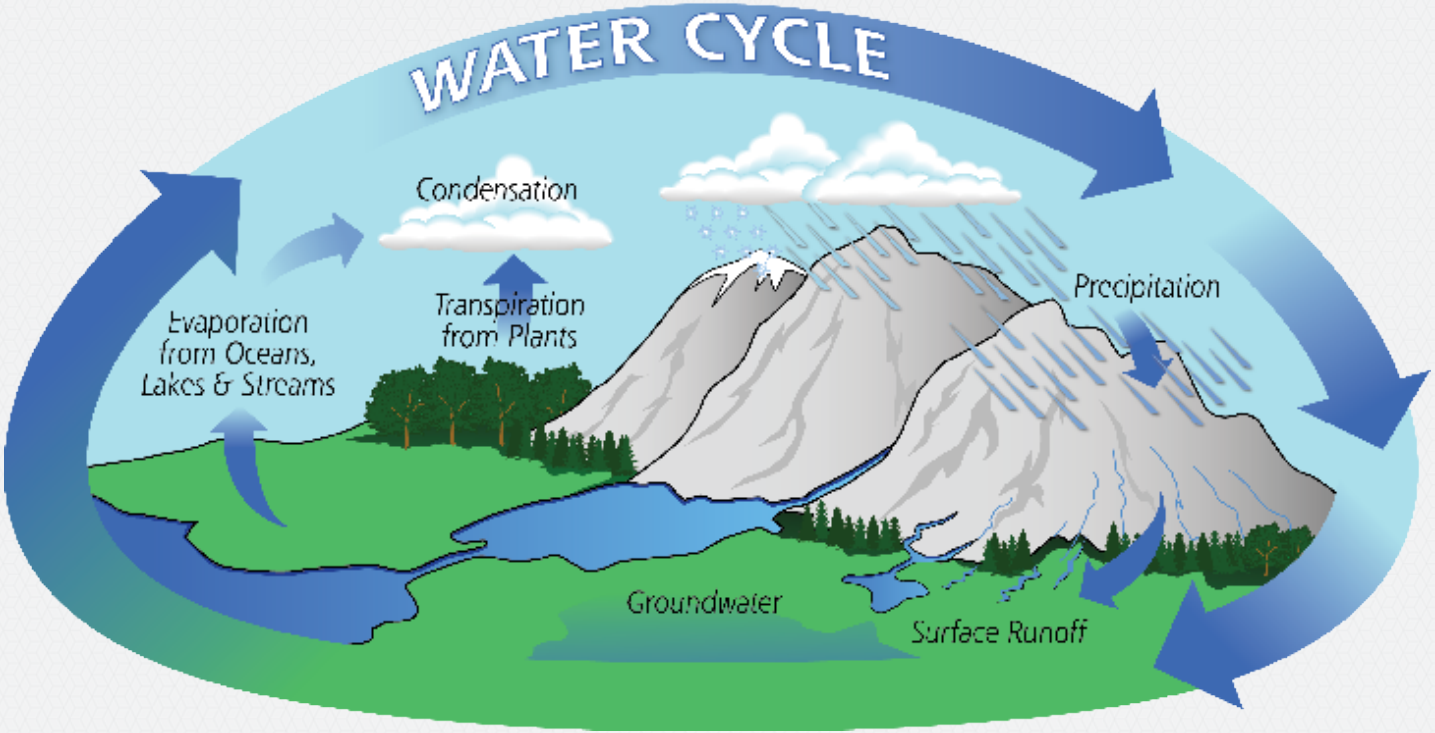
Try to think about the water you normally use every day. Ask yourself some questions like: where does my water come from? Where was my water last night? Last month? Last year? Ten thousand years ago? What happens to water when I use it? Where does the water go after I take a shower? Could be possible to recover something from the dirty water?
To answer some of these questions, we must first understand some aspects of natural cycles.

Water Cycle on Earth

Different natural cycles are happening on our planet. Everyday living beings die, and new life is born. Rivers and changing sea levels destroy the land, and geological processes such as volcanism create new land. These natural cycles maintain planet earth as "a state of dynamic equilibrium," in which everything is constantly changing.

Among the many natural cycles, the carbon, oxygen and water cycles, powered by solar energy from the sun, are the most critical, because, without them, life, as we know it on Earth, could not exist. Water moves in a continuous cycle between the air, ground, plants, and animals.

The water cycle is the most straightforward natural cycle on Earth. Solar energy draws water from the ocean, lakes, and rivers. Millions of liters of water rise invisibly into the atmosphere as water vapor. This process is called evaporation. Water vapor forms over the oceans through evaporation and is blown onto the land by winds. There it meets the mountains, rises, cools, and forms clouds of tiny water droplets in a process known as condensation. The droplets fall to earth as rain, snow or ice (hail), which we can know as precipitation. The earth also soaks up some of the water. During this collection process, the water is stored in the ground (also called aquifer) until it is needed. Later, the water runs into streams and rivers, and eventually flows into lakes or the sea, evaporation takes place, and the cycle starts all over again.


WATER CYCLE
Condensation
Transpiration from Plants
Evaporation from Oceans, Lakes & Streams
Precipitation
Groundwater
Surface Runoff

2. UNDERSTANDING CONCEPTS:

Water conservation

Many people pump water directly from an underground aquifer and use it for their daily use. Other people can also take their water from other sources like rivers, dams or lakes. It depends on the place they live.

In any case, it is very important to treat this water before consumption, especially if you want to drink it!

Having access to water is essential to human health. However, in the last decades, the access to fresh water has become crucial in many places around the world, and the global increment of the population and climate change are making many countries drier. The World Health Organisation estimates that nearly a quarter of the world's six billion people currently lack access to good quality water for drinking, personal hygiene, domestic use or sanitation. For example, for us, it is necessary to use about 200 liters of good quality water every day.

We must take care of our environment to have access to that good quality water!!

Wait... What is good quality water?

Good quality water can include water for the environment, for stock, human consumption (like drinking water), cropping and treated surface water, as well as untreated and uncontaminated water from springs and wells. Without good quality water, people cannot lead healthy and productive lives

Drinking water is defined as water intended primarily for human consumption but which has other domestic uses. It may be consumed directly from the tap, indirectly in beverages or foods prepared with water, or for bathing and showering. Ideally, it should be clear, colorless and well-aerated with no unpalatable taste or odor and it should contain no suspended matter, harmful chemical substances or pathogenic microorganisms (like bacteria, viruses, and protozoa).

While it seems like we have an endless supply of water, we don't! Nowadays, many rivers and catchments are polluted by industrial, agricultural and human waste, while other sources including groundwater are drying up. People are using water faster than nature (water cycle) can replenish it.

2. UNDERSTANDING CONCEPTS:

We must do everything we can to conserve our fresh water supply

Can you imagine not having enough water to use in your daily life?

Matching Game: How Much Water?

Draw a line matching the items on the left to the amount of water on the right.

1.	Taking a shower ☐	A. 113 Liters
2.	Watering the lawn ☐	B. 4466 Liters
3.	Washing the dishes ☐	C. 15-26 Liters
4.	Washing clothes ☐	D. 2 Liters
5.	Flushing the toilet ☐	G. 50-100 Liters
6.	Brushing teeth ☐	I. 4 Liters
7.	Drinking ☐	J. 30-80 Liters

Let's be Water Wise!
We all have the power to save water. Teach your family that saving water is good for people, plants, and animals, and also saves money on the water bill! Lead by example. Each drop you save adds up to a river!

1. Turn off the tap. Water is precious! Don't let it run! Turn off the tap when washing hands, brushing teeth or doing dishes.

2. Take a shorter shower.

3. Fix leaky plumbing. Small drips add up to wasted water and money! Ask your family to fix leaky taps and toilets, and install water-efficient plumbing fixtures.

4. Don't let the hose run. When watering plants or washing the car, use a spray nozzle that lets you control the water flow when you need it.

6. Make better food choices. Since raising cows for meat uses so much water, try to eat less beef when you have the choice.

7. Don't use the toilet as a trashcan. Toilets are only meant for human waste

2. UNDERSTANDING CONCEPTS:

Resource recovery from wastewater

We have learned that every drop counts and water is a vital resource. We turn on the tap and water appears. We flush the toilet, and our waste disappears. As if by magic – out of sight and out of mind. However, it is not that simple.To get drinking water ready to consume different processes must be carried out to clean and maintain its quality. These processes take place in a water treatment plant, which is a facility where impurities such as clay, microbes, and color are removed, making it safe for people to drink. This cleanup step is essential, but have you ever wondered how the water is handled after you have used it to ensure that you and our environment are protected?

The water that we used and escapes typically through the sink and pipes in our homes, schools, buildings and other public places is called wastewater. It comprises used water from domestic toilets (generally called sewage), kitchens, bathrooms and laundries (often called grey water). Used water from manufacturing and processing plants is also part of wastewater. Wastewater is 99.97% liquid, and the balance is a small amount of solids and dissolved matter.

Why is necessary to treat wastewater?

Until relatively recent times, wastewater was disposed of without being treated, and in many parts of the world, this still happens, contaminating the sea, rivers or lakes. The result was polluted water and many serious diseases such as cholera, which is an infectious disease that causes severe diarrhea. It can lead to dehydration and even death if untreated. It is caused by eating food or drinking water contaminated with a bacterium called Vibrio cholerae. That is why it is very important to treat wastewater before it is discharged.

We can also find good microbes in wastewater!!

FROM WATER CONSERVATION UP TO RESOURCE RECOVERY FROM WASTEWATER OR MUD

We can find many things in wastewater. There are solids and dissolved matter, which can be organic or inorganic. Organic matter is composed of carbon-based compounds and includes dead matter and living microbes, which come from the waste we produce. Many of these microbes can be dangerous for us, but many others are good guys too!!

If there are favorable conditions, the good microorganisms can eat the dead organic matter, which is surrounding them and produce useful products for us. Inorganic matter like sand, mineral, salts are also present in wastewater and sometimes it is also possible to concentrate and recover some of them!

Wastewater is also a source of valuable products; we just need to find the way to recover them!!

Energy recovery: Microbial fuel cells

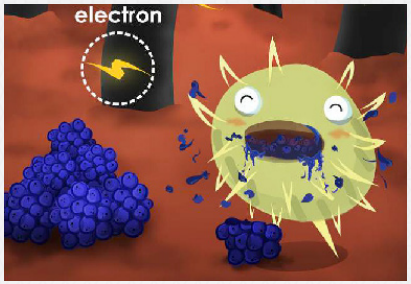
We know that microbes are tiny organisms that are too small to be seen with the naked eye. We need a microscope to see them. Even though they look so small, they are essential players in the recycling of nutrients on earth and provide key ingredients to support life. There are three main types of microbes: bacteria, fungi, and viruses. We can find these microbes in wastewater, but bacteria are commonly key players and dominant.

How do microbes get their energy?

All living organisms need energy to live. This energy comes from the energy stored in the chemical bonds of food that is released when we “burn” the fuel. There are different ways organisms get their food. Some organisms are autotrophs, meaning they take inorganic materials from the environment to

make organic material (they make their food). Other organisms (like us) are heterotrophs, meaning they rely on external sources of organic matter from which they can get their energy. Bacteria can be autotrophs or heterotrophs and can get their energy from wastes (like wastewater or mud) containing organic matter.

How bacteria break down food to release energy (metabolic processes)



All organisms need to metabolize or break down their food so that the stored energy can be converted into energy which can then be used to grow, repair and reproduce. Bacteria, for example, use cellular respiration to burn the organic matter releasing energy stored in the chemical bonds of the food (organic matter). They have enzymes, which are chemical compounds that help to break down these chemical bonds and obtain the energy stored. When oxygen is present, the electrons are taken up by it and the process referred to as aerobic respiration (oxygen is the electron acceptor). When the oxygen is not present, other elements such as iron or sulfur (inorganic matter) can accept the electrons, and the process is called anaerobic respiration. For most of the bacteria these metabolic processes occur inside the cell, but for a unique type of bacteria, the electrons are given off externally to an acceptor. These special bacteria are called electrogenic bacteria.

We can find electrogenic bacteria in nature, in every type of soil, sediment and surface water environment where oxygen is limited

What are Microbial Fuel Cells?

Microbial Fuel Cells (MFCs) generate electricity using the natural ability of microbes to produce electrical power when they process food. The special bacteria called electrogenic bacteria are the key to how a microbial fuel cell works!!

Microbial fuel cells work because anaerobic bacteria create a thin film on an electrode. This electrode can be buried in soils or sediment. As it was mentioned before, electrogenic

bacteria can give off their electrons outside of their body to an external acceptor. In a microbial fuel cell, electrogenic bacteria deposit their electrons onto this electrode (external acceptor called anode), which can be made of graphite fiber.

As we can find electrogenic bacteria naturally in soil, mud, sewage, and wastewater Microbial fuel cells can be done pretty much anywhere!!

In the figure below you can see the different processes happening in a microbial fuel cell:

Fig 1: MudWatt

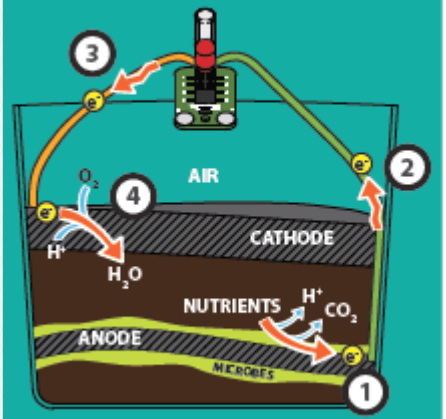


Figure 1 shows the **flow of electrons** through a MudWatt:

1. As the microbes around the anode munch up the nutrients in the mud, they **deposit electrons** onto the **anode** in one of three ways, as illustrated in **Figure 2** below.
2. These electrons travel through the wire to the **Blinker Board**, where they power the electronics.
3. The electrons then travel back down through the wire to the **cathode**.
4. At the cathode, electrons interact with oxygen and protons to form **water**.

This cycle happens over and over, trillions of times every second. This continuous flow of electrons is what we call **"electricity"** which can power small electronics.

3. PRACTICAL SESSION:

Exercise 1 (imaginations)

As we have learned, bacteria are tiny organisms and some of them can eat organic materials to get electrons and produce their energy without oxygen. If the bacteria are electrogenic, they can give off the electrons to an external acceptor, like an electrode. This process occurs mainly inside the cell. Can you imagine it how it looks? Let´s draw how you imagine electrogenic bacteria producing electricity from organic matter. We can do it in three steps, add different colors!

1) Electrogenic bacteria break down organic matter (food) and get electrons

2) Electrogenic bacteria are together forming a film and delivering electrons at the surface of an electrode

3) Electricity is produced, and now you can turn on different devices

HANDS TO WORK, LET'S PRODUCE ELECTRICITY FROM WASTEWATER!!

Let´s build a Microbial Fuel Cell, let´s build a MudWatt and recover some energy from mud and wastewater!!

Now it is time to build our Microbial Fuel Cell. Ask for the MudWatt guide.

3. PRACTICAL SESSION:

Exercise 2 (questions, observations and desires)

Once you have built the MudWatt (Microbial Fuel Cell), write down your observations and answer the next questions:

1. Is the MudWatt already producing electricity? If not, when do you think it will start the blinker? Explain your answer.

2. Once you see the LED blinking, start to count how many times it blinks in one minute. Write down the numbers! After how many days day it reaches a maximum blinking?

3. It could be possible to speed up the blinking of the MudWatt feeding with additional "food". Order from best to worst the next options to feed up electroactive bacteria and increase the production of electron transfer in time: Sugar, wood powder, smashed potato juice, vinegar grass. Explain your answer

HANDS TO WORK, LET'S PRODUCE ELECTRICITY FROM WASTEWATER!!

4. Other possibility to change the speed of the MudWatt blinking is increasing the temperature. Order from best to worst the next options of temperatures and think at which temperature electroactive bacteria will feel more comfortable to generate electricity: 40°C, 20°C, 37°C, 50°C, and 70°C. Explain your answer

5. At this point you have heard and learnt about water conservation, wastewater, energy recovery using bacteria and Mud. What are the main problems you can recognize with water pollution in your community? How do you think they can be solved? Are Microbial Fuel Cells an alternative or maybe other technologies? Discuss!

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