Studying the movement of bubbles in a tube for methane extraction in Lake Kivu

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Introduction

- Lake Kivu lies on the border between the Democratic Republic of the Congo and Rwanda.
- It's almost the size of Mauritius and has a maximum depth of 480 metres.
- Lake Kivu also stores huge amounts of methane gas which Rwanda is extracting to produce electricity.
- The best approach to eliminate any risk for a gas eruption would be to completely remove all the gases from Lake Kivu immediately.

Development of Methane in Lake Kivu

- Lake Kivu contains exceptionally large amounts of dissolved carbon dioxide and methane in its deep waters. These gases have accumulated over 800 to 1000 years.
- The carbon dioxide originates from two active volcanoes at the lake's northern side: the Nyiragongo and the Nyamuragira.
- These 20,000 year-old volcanoes are among the most active in the world.
- The methane comes from the degradation of organic matter produced at the lake's surface (representing one third of the methane produced in Lake Kivu) and the second process – which produces most of the methane in the lake – is the conversion of carbon dioxide into methane.
- The concentrations of carbon dioxide are five times higher than the concentrations of methane.

Gas Accumulation

- Such a large accumulation of methane in a lake is unique, and has never been reached in any other lakes.
- This particularity is caused because the gases are being trapped in the deep waters by an inflow of deep sub-aquatic spring containing warm, salty and carbon-dioxide rich water. This effectively creates a seal.
- Currently, $45km^3$ of methane are economically viable for extraction, which could generate as much as 500 MW of electricity over 50 years.

Benefits of using methane from Lake Kivu for electricity

- The dissolved gases pose a risk to the local population, as they could potentially erupt from the lake
- A large disruption such as a landslide could trigger gas bubbles to rise to the surface and erupt without warning signs
- By removing methane, the chances of a gas eruption are strongly reduced because there's less pressure.
- Extracting methane will produce electricity, which is crucial for Rwanda's development.
- It currently has 225 MW of installed generation capacity and 53% of the country has access to electricity.

Projects extracting the gas

- The Rwandan government plans to reach an electrification rate of 100% by 2024.
- KivuWatt power plant run by Contour Global, already extracts methane to generate electricity.
- The first phase already generates 26 MW of electricity. It will reach 100 MW in the second phase.
- Shema Power Lake Kivu Limited, formerly Symbion Energy has a project with a plant which provides 56 MW
- Gasmeth is building a gas extraction facility to generate and sell compressed natural gas in bottles.

How does the extraction process work?

- Methane extraction occurs in an area called the "resource zone", at a depth between 260 and 480 metres, where most of the methane is concentrated.
- Using a long pipe, deep water is pumped onto a floating platform. As the deep water moves to the surface in the pipe and the water pressure reduces, the gases separate from the water. The mixture of gas and water arrives in a separator, where the gas is further extracted.
- At this stage, the gas contains a high concentration of carbon dioxide and so it goes through a purification process to enrich it in methane. This is then moved through a pipeline to the generators.
- Given the uniqueness of Kivu methane deposit, there are no other lakes in the world where methane is extracted in this manner.

Methane extraction

- extract a quantity of water from lake through a tube at 320 m in the lake down into the Resource Zone (extraction)
- on the platform, extracted gas and water are separated (separation)
- bubbles are formed and their buoyancy drives the upward flow in the tube in a continuous and self-sustaining mode (self-siphoning).
- After washing the extracted raw gases (mainly retaining H_2S and CO_2 in the lake water), water without gas is returned to lake at depth of -90 m (re-injection)
- from the gas the power is produced (production)

Gas extraction, and water return

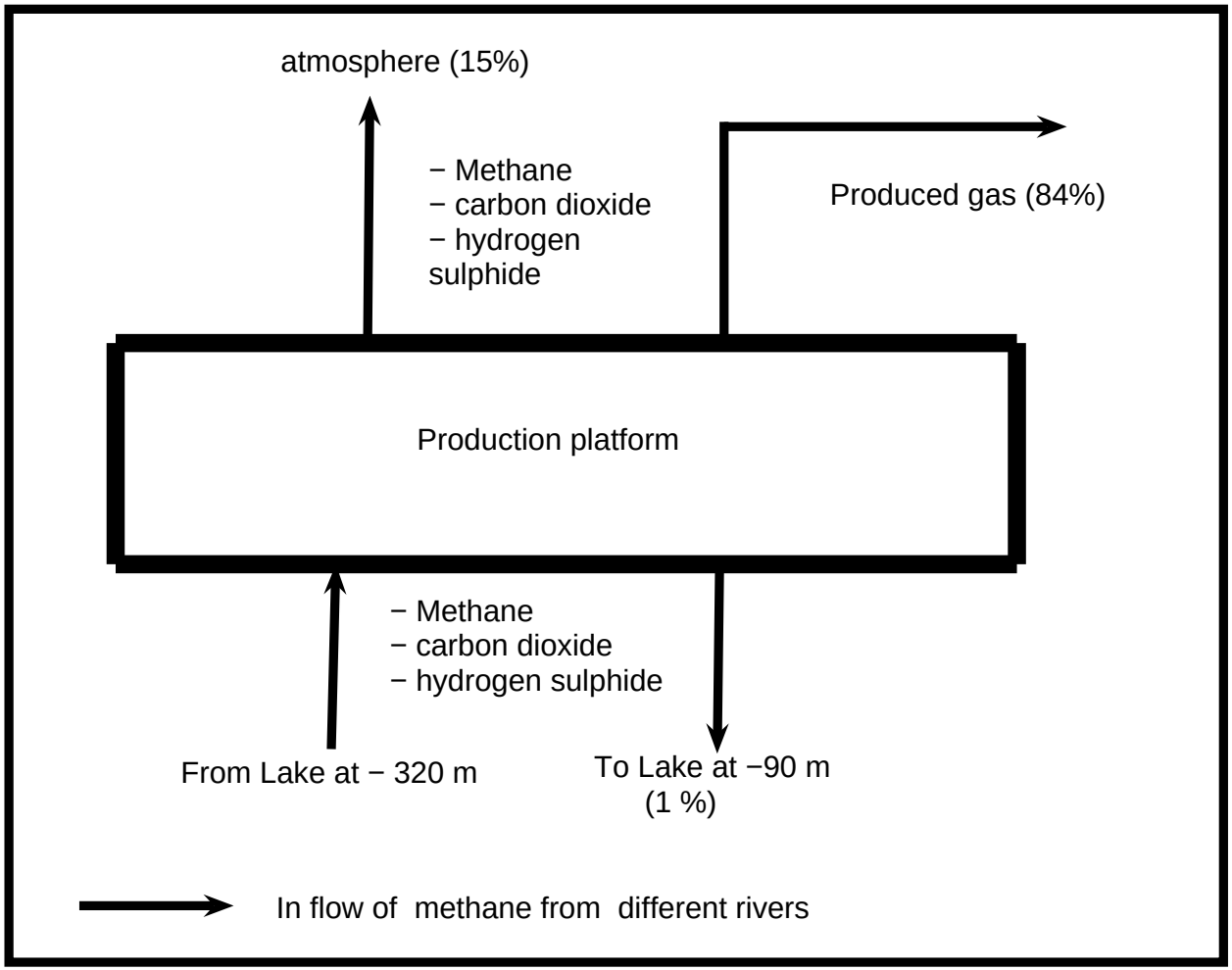

Figure: Gas extraction concept.

Negative impacts from gas extraction

- The extraction process could disturb the lake's layers and may increase the risk of gas eruption. To avoid this risk, models are needed to predict the acceptable depths to extract and release the deep water.
- Modification of the lake ecosystem, from algae to fish. Deep water contains much more nutrients than the surface water and releasing it into the surface could have catastrophic consequences for the biodiversity.
- Nutrients could generate a high production of algae that deteriorate the water quality and the food chain
- Waste of the gas resource, if the methane operator is not extracting it in an efficient way.

Bubble Movement

- We describe the motion of a small spherical bubble in an inviscid liquid which is in forced oscillation with an up and down movement. The theory gives the frequency at which the downward force due to oscillation balances the buoyancy force; in this condition there is no net movement of the bubble.
- Bubbles are governed by the interactions between air and liquid. There are many factors to be considered when attempting to simulate the deformation and movement of bubbles.
- There are two flows to consider i.e.,those occurring inside and outside of the bubble bodies.

Problem

- A tube is injected into the resource zone (Layer 4), where high pressure causes bubbles to grow, and the buoyancy of the bubbles pushes the tube upward flow.
- The production, proliferation, and movement of bubbles within the tube are all things we're interested in studying (prior knowledge of its diameter is an added value).
- What determines where bubbles emerge initially when the temperature is raised to the point where the water is saturated with dissolved gases?
- Will bubbles appear at random along the length of the tube?
- What factors influence bubble size?