LAKE KIVU AND ITS GAS

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***Lake Kivu and Gas Extraction*. Tell us more.** To inform the technically interested readers in Rwanda we set out to describe some basics of Lake Kivu and its gas. Our focus is mainly on the extraction and we often run into people who have questions. Nothing of the knowledge we have accumulated is secret and we are happy to share that with you. Some of what we present may be over simplified as to reach a wide audience.

Often people ask about Lake Kivu and then assume that the gas of Lake Kivu is drilled for and extracted from under the Lake. Or they ask or wonder how dangerous is Lake Kivu, if the Lake will explode. Other questions are about the gas extraction and if such is dangerous.

***A unique and situation*,** even NASA shares their satellite images of the Lake. We can safely say that Lake Kivu is carefully monitored by experts and scientists. The gas extraction, which currently takes place in the lake, is a unique technological application of engineering and physics. It offers a good economic opportunity to Rwanda and DRC if done well. All operators are monitored by the Lake Kivu Monitoring Programme. From that background the above questions are answered using the knowledge available to date. However, it is always to be remembered that gas extraction is unique in the world. In addition, some scientists qualify Lake Kivu as a living laboratory. More researches need to be done to have a better understanding of the Lake's behaviour. The views presented here are the most probable interpretations, according to current knowledge on the Lake.

***Do we drill for the Gas*?** The answer is simple: No! The gas is dissolved in the water like the gas in your soft drink or beer. When you take off the lid, bubbles form. These bubbles are CO_2, carbon dioxide. It gives this fuzzy sensation when you drink a cool drink. In the Lake we have three main gasses dissolved in the water, CO_2, CH_4 and H_2S, respectively Carbon Dioxide, Methane and Hydrogen Sulphide. CO_2 and CH_4 are odour less gasses. H_2S can be smelled, when in low concentration. All three gases if emitted/released in large quantities can have fatal effects. The typical thing about Lake Kivu is that it has variations in properties from the top to the bottom. The heavier water stays at lower levels that is also where most of the gas is concentrated. There are 5 distinct water layers. Scientific studies show that these layers are very stable and keep the gasses in place. So the water on top exercises the pressure that works as the lid on your soft drink. The amount of dissolved gasses increases as you go deeper in the lake. We say that the concentration of gas increases; this is measured as partial pressure.

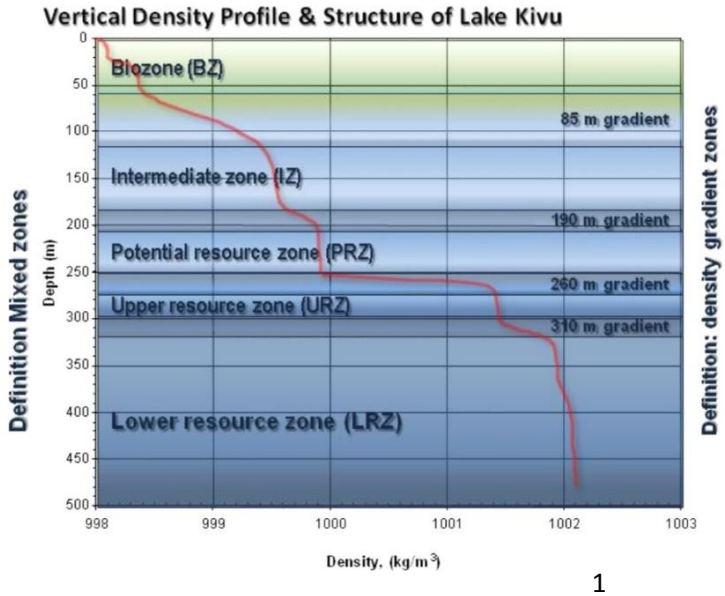


Figure 1. The red line gives the density (weight/m3) of the water. And you can see that the heavy water is at the bottom.

***Will the Lake explode*?** That seems to be unlikely. Studies over the past decades indicate that such would be improbable. Current knowledge makes us to believe that it is not likely to happen soon. So people ask us another good question: Can something trigger the lake to turn? Nowadays, this is very unlikely because even big under water volcanic eruption can't destroy the stability of the lake. However in the future, if methane gas is not extracted from the lake, the risks of gas eruption will increase. As a matter of fact, methane gas, with its high partial pressure, is the trigger elements of gas eruption. Its recharge in the lake increases the total pressure of the gases in the lake, what increases the risks of gas saturation. Methane gas extraction reduces the risks of gas outburst. However, inappropriate gas extraction can also have negative impacts on the Lake. Let us therefore look at some basic aspects of Lake Kivu and the extraction of methane gas.

***The lake waters are layered*, see the image above.** The first 40 to 60 meters is the Bio-zone. Here is where we find oxygen and living organisms, there is where we find life. The depth of the oxygen layer (the biozone) depends on the season and winds. With more wind there is more motion in the water and the oxygen holding layer is bigger. That means the bio-zone is deeper. Interesting thing to know is that fish follows the depth of the oxygen as they hunt for their food, the planktons. The plankton has an escape from the fish by going deeper to where the oxygen is less. Below the bio-zone, so below 40 – 60 meter there is no oxygen. In deeper waters there is no life. The top water of the Lake has a high pH, meaning that the water is alkaline, has a tendency of soapiness. This is the contrary to acidic at the bottom by 500 meter deep. Soap is alkaline and vinegar is acidic. At the bottom the Lake is more acidic and we find a pH of about 6.

Now if we go deeper towards the bottom we see that the density increases. At the surface of the Lake water gas, the density is of 998 kg/m3 while at the bottom; by 500-meter-deep it can reach 1002 kg/m^3. That is 4 kg difference per cubic meter. When going deeper the concentration of gas increase. In particular the concentration of CO_2 and CH_4 significantly rise. Below 300 meters we enter into the lower resource zone, here we find the gas that is currently extracted by KivuWatt. To extract the gas more efficiently technological innovation on gas extraction is really needed. Here we have a challenge for young engineers and industry, universities and innovation centres. This is an innovation challenge to applied science engineers and researchers.

***Stability of the Lake*.** In the Lake there is no mixing between the layers. This makes the layers stable. Layers are separated by gradient of density. The main gradient is found at 260 mtr depth. It is a general scientific consensus that the layers are stable and will not be disrupted easily. One has to know that this stability has been studied over the past years in-depth, and these studies have to continue to exactly quantify which forces can disrupt them. There is also a need of more independent and new thinking to give interpretation to the Lake. This is another innovation challenge for the applied science and applied research.

The contemporary insight is that the dissolved gas is kept at various depths as a result of the layering and absence of mixing of layers. The layers have proven to be stable also during various accidents such as earthquakes; eruption of volcanoes or marine works incidents of dropping anchors and pipes, the sinking of a ship did not trigger spontaneous gas release. We have thus empirical reason to believe in the stability of the Lake.

***Is the Lake dangerous*?** It is hard to say how dangerous the lake is. The gas will continue to accumulate and in the end the total gas pressure will become higher than the Hydrostatic of the water, the gasses will then release themselves. Such an eruption on Lake Kivu would have catastrophic impact beyond human imagination on and around the Lake. This might happen every thousand years as the gasses are gradually accumulating. Dangers are to be mitigated as much as

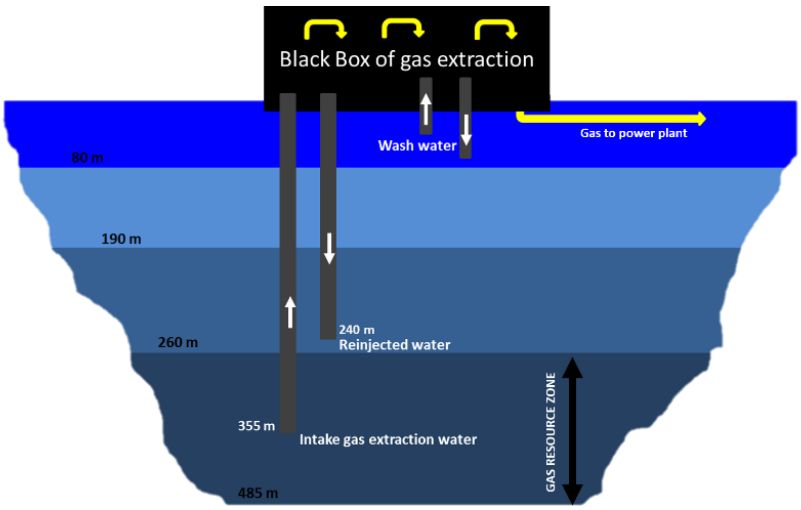
possible or managed in case we can't avoid them. The logical solution would be to remove the gases, especially the trigger one which is methane. This can be done by extracting Methane, mainly and Carbon Dioxide if possible. So if there is a choice between doing nothing and extracting the gas, gas extraction should be favoured.

When extracting the methane gas, the ± 55 km^3 of methane in the Lake gets also an economic value. Removing the methane gas from the waters reduces the risks of sudden turning. A good spin off then is the production of electricity. Removing gas implies reducing the gas pressures, this helps to maintain control over the Lake. This extraction has to be done in a safe and sustainable way.

***Is extraction safe*?** The extraction of gas is preferred over leaving the Lake as it is, extraction is perceived as less dangerous and a risk mitigating action. It should for good reasons be done in a competent manner by professional engineers and companies with high levels of integrity. These efforts have to be inspected and supervised. Supervising and guiding the gas extraction is a very delicate and complex affair. That also will require quick reaction and quick responses and a well-equipped inspection team. Continuous measuring is required, continuous inspection of the gas extraction and effects on the lake should be part of that. This is work with a time horizon of 100 years and the costs for that can best be carried by a fair payment for the gas extracted. There is in fact daily measuring and monitoring to be done. It is also needed that current insights are challenged and in particular that we keep analysing the effect of the re-injected waters and gas on the stability. The amounts of water displaced are gigantic and these should not undermine the current stability of the Lake. A strong and flexible managed authority able to make the required investments timeously should be put in place.

Urgent studies are to be implemented and an inspecting authority should be allowed a management style that is responsive and can handle various scenarios. So to answer the question, yes there are enough reasons to believe that gas extraction can be done safely. Yet we can only know that after years and only if indeed monitoring, inspections and innovations take place in the time and as set-out to mitigate risks. An alert and flexible management system should form the back-bone of the inspecting Authority. Here is again another innovation challenge for the management scholars in Rwanda to add some insights.

A question people do not ask is: What is needed to secure proper monitoring and inspection to secure a safe gas extraction? Next time!



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