How to tackle the regulation ruling the methane gas exploitation at Lake Kivu

Michel Halbwachs – Data Environnement – Novembre 17th 2011

Generalities

As of 2011, several companies have started extracting methane gas from Lake Kivu, or are building extraction platforms.
Two workshops were held, in 2007 and 2011, in the presence of the government authorities of Rwanda and the Democratic Republic of the Congo, the two lakeside states. Each time, they expressed their wish for a regulation concerning the extraction stations. All of the participants – political staff, scientists, investors, industrial designers, potential sponsors – agreed that regulation texts must first be established before starting an industrial exploitation of the gas.

Three main themes are of concern for a regulation:

- The environment of Lake Kivu must be respected, and more specifically its upper, living layer, called the biozone. This consideration sets constraints upon the process of degassed waters rejection, because their richness in dissolved salts (nutriments) would be harmful to the biozone.
- The extraction of the gas from the deep waters of the lake must be optimal. This natural resource, a true treasure for the neighboring countries, however extensive, is still limited and should not be wasted. A coefficient should be defined to qualify an extraction process' efficiency, and a minimum value should be assessed.
- Any extraction process must comply with a demand for reducing the risk of a gaseous explosion in the lake, of the kind of Lake Nyos' explosion in Cameroon in 1986. Such an accident on Lake Kivu could cause more than a million victims among the surrounding population.

Objectives

Technically, the regulation texts should address two hard-to-solve questions:

1) Where to reject the nutriment-rich degassed waters?

The process must preserve the present and future environment in the living part of the lake (the biozone), situated between the lake's surface and a depth of 30 m to 60 m, depending on the seasons. A massive inflow of nutriments (salts such as phosphates and nitrates) into the biozone would cause an eutrophisation, i.e. an excessive development of organic matter, with a consequent diminution in dissolved oxygen. Bloom algae's would proliferate, and the animal species would be endangered.

2) How to extract as much of methane as possible, while spending a minimum energy in the process?

Wasting the methane in the rejected waters should be avoided. Hence the need to define a performance coefficient, qualifying the energetic efficiency of a station. A minimum threshold for this coefficient should be set, that the extraction stations should satisfy.

The regulation texts should also consider how the risk of a gaseous explosion evolves, in function of the proposed rejection process for the degassed waters.

Historical background

An international workshop on the lake's survey during methane extraction was held in Gisenyi in March 2007 under the aegis of the World Bank, in the presence of the concerned ministers from Rwanda and the RDC. At the outcome of the workshop, a "comity of experts" constituted itself, aimed at writing a document to rule the exploitation of methane in Lake Kivu. The final version of the text was published on June 17th 2009, under the title "Management Prescriptions for the Development of Lake Kivu Gas Resources", in abridged: "MPs".
We were in disagreement with the contents of the MPs, notably in what concerns the rejection process for the degassed waters. Data Environnement ordered an expertise of this proposed rejection process to a company specialized in fluid mechanics, YLec Consultants. The expertise was issued three months after the MPs publication, under the title “Exploitation of Lake Kivu Gas Resource - Consequences of the re-injection of degassed water into the Resource Zone, September 2009". This report confirms our criticism towards the MPs.

In February 2011, a second workshop was organized in Gisenyi, again with authorities from Rwanda and the RdC. We exposed our criticisms on the content of the MPs, and advocated the necessity of submitting the problem to an independent and competent expertise company. At the end of the workshop, this principle was unanimously approved by the participants.

In April 2011, we published our own propositions, hereafter abridged as "TextReg", concerning methane exploitation in Lake Kivu, under the title "Regulation Ruling the Methane Gas Exploitation at Lake Kivu". A French and an English version of this document, as well as the expertise report from YLec Consultants, can be found on http://www.dataenvironnement.com/kivu2011/

Present situation

The MPs are grounded on the following principle which was nowhere clarified nor justified : the waters taken from a given layer must be rejected, after degassing, into the layer itself. This applies for the "resource", this particular layer in the lake where methane is present in the most interesting concentration.

The TextReg insists that rejected waters should in no case be sent back into the resource. It explains that rejecting into the resource would dilute it. Methane concentration would diminish and the extraction process would rapidly lose its efficiency, leading to a vast waste of the henceforward unextractable gas resource. The TextReg proposes to reject water into another layer.

There is no middle solution between the two propositions : the MPs and the TextReg are irreconcilable.

Choosing between the propositions

A thorough evaluation of both propositions must be performed.

The effects of water rejection into some layer involves complex phenomenon in the domain of fluid mechanics which governs dilution with turbulent currents, as applied in a lake's context with stratified layers. Special competences are definitely needed, backed by sophisticated software modeling tools and powerful computation resources. Presumably no single "expert", from the board which wrote the MPs or from elsewhere, can alone master these competences and tools. Personally, after 20 years of work on Cameroonian lakes and Lake Kivu, I don't consider myself as an expert of fluid mechanics applied to lakes.

Only some company specialized in fluids mechanics is apt to lead this kind of study. Such an organization should be hired for an expert evaluation of the propositions at hand.

The chosen company should examine the existing texts and comment on their contents.
Of course, it should be free to propose any other, better adapted solution.

Enforcing the regulation texts

Since the first workshop in Gisenyi in March 2007, the self-established experts committee raised the question of how to verify that the operators of methane exploitation on Lake Kivu respect the MPs.
The members of the committee have in majority been individually implied in some extraction projects. It seems essential that the enforcement of the regulations texts should be incumbent upon a specific structure, with no member having a former or present responsibility in any methane exploitation project on Lake Kivu. We suggest that this responsibility be given to the independent and competent firm or organism in charge of expertise for the regulation texts.

Conclusion and proposition

We believe it is essential to define and implement a regulation concerning the methane exploitation in Lake Kivu. This regulation should be adopted and made official by both lakeside countries.
Without such a regulation, one can foresee an anarchical development of extraction projects, led by firms with no competence in the domain, in mere search of profits, with the following consequences:

1) a possible pollution of the living part of the lake,
2) a possible de-stratification of some water layers in the lake,
3) a possible increased risk for a gaseous explosion,
4) an almost certain vast waste of the gas resource.

The whole lake's destiny is at stake.

Points 1) to 3) pertain to the rejection method adopted for the degassed waters. This delicate question is in particular need for an indisputable expertise, as said above.

Point 4) concerns the efficiency of an extraction process. Common sense dictates that a simple rule to avoid wasting the resource would be to impose a threshold in the processes' efficiency, namely for the tolerated methane concentration in the rejected waters.

Since the March 2007 workshop, efforts to improve the regulation texts have been unsuccessful, and at the present time the situation is blocked. Some discouragement seems to prevail, or even an attitude of not facing the problem and putting it aside. We believe this situation to be very noxious for the gas extraction project and for the future of Lake Kivu.

We think it possible to find a sensible way to unblock the situation through a two step solution:

- In the short term, define a performance threshold to be obeyed by the implied companies in extraction. For instance, define the proportion of produced to consumed energy to be 80 %. This criteria should address not only the electrical consumption of the stations, but also – this is essential – the proportion of the quantity of methane rejected with the degassed waters to the quantity of methane present in the incoming waters. This proportion should be less than 20 %.

- In the medium term, organize a requirement for an expertise from some independent and competent office, concerning the place and method for water rejection.

APPENDIX

Existing documents concerning regulation

❖1) An expert committee constituted on the initiative of John Boyle, World Bank,
committee members : Finn Hirslund, Philip Morkel, Martin Schmid, Klaus Tietze, Johny Wuest
- Management Prescriptions for the development of Lake Kivu gas resource
17 June 2009 (35 pp.)
- Prescriptions de gestion pour le développement des ressources en gaz du lac Kivu
17 Juin 2009 (41 pp.)

❖ 2) Data Environnement
- Textes réglementaires régissant l'exploitation du gaz méthane du lac Kivu (32 pp.)
Michel Halbwachs - 23 Avril 2011
- Regulation ruling the methane gas exploitation at Lake Kivu (32 pp.)
Michel Halbwachs - April 23th 2011
- Choix du site des concessions d'exploitation (17 pp.)
Data Environnement – Avril 2011
- Siting concessions for methane exploitation on Lake Kivu (17 pp.)
Data Environnement – April 2011

❖ 3) YLec Consultants
Exploitation of Lake Kivu Gas Resource - Consequences of the re-injection of degassed water into the Resource Zone (86 pp.)
Guillaume Maj, September 2009

❖ 4) EAWAG
Modelling the reinjection of deep-water after methane extraction in Lake Kivu (35 pp.)
June 2009

❖ 5) Kivu Gas
- Mandatory Technical and Administrative Requirements (30 pp.)
Philip Morkel, July 2009
- Lake Kivu Concessioning Philosophy (20 pp.)
Philip Morkel, July 2009

❖ 6) PDT GmbH
Basic Plan for Monitoring, Regulating and steering exploitation of the unique methane gas deposit in Lake Kivu: safely, environmentally soundly and with optimal yield (201 pp.)
Klaus Tietze, 31 May 2007

❖ 7) COWI
An additional challenge of Lake Kivu in Central Africa – upward movement of the chemoclines (15 pp.)
Finn Hirslund J. Limnol. 71(1), 2012

Notes about these documents

Document 2, proposed by Data Environnement, was written after the March 2011 workshop in Gisenyi, as an answer for the presented Mandatory Prescriptions (MPs, documents 1). It is a constructive criticism which shows the weak spots of the MPs and proposes an alternate solution. The solutions in document 1 or 2 are irreconcilable. The MPs consider that the degassed waters must be rejected into the resource; the regulation advocated by Data Environnement insists that rejection waters should in no way be rejected into the resource.

Document 3 is a scientific and technical analysis of the MPs, which was achieved by YLec Consultants, a research office which specializes in fluids mechanics. It was issued 3 months after the MPs. It' conclusions are severe: putting the MPs in practice would inevitably induce a dilution of the rejected waters into the resource and lead to a vast waste of the methane contained in the lake.

Document 4, issued by EAWAG, lists the pros and cons for each of various solutions for degassed waters rejection. It can be noted that the PR1 solution proposed in document 2 from Data Environnement is accepted, although one of the solutions proposed in the MPS is preferred (solution RZ6).

Document 5, written by Philip Morkel, is modeled on the MPs.

Document 6 was written by Klaus Tietze. A solution is presented which radically differs from the MPs. Besides, Klaus Tietze refused to sign the MPs and demanded in written that his name be crossed off from document 1.

In document 7, Finn Hirslund aims at reducing risks and advocates partly rejecting degassed waters into the mixolimnion, in complete contradiction with the MPs.

In conclusion, if we correctly understood each position, among the 5 members of the committee the MPs are:
- judged indispensable by Philip Morkel,
- seemingly favorably judged by the members of EAWAG,
- definitely denied by Klaus Tietze et Finn Hirslund.

Optimal exploitation of the methane resource in Lake Kivu

Michel Halbwachs – Data Environnement - November 17th 2011

Generalities

The table below summarizes the capacities and concentrations of the methane in each layer.

	Depth (m)	Water volume* (km^3)	Methane volume (km^3)
IRZ**	60 – 160	176	7
PRZ**	160 – 260	138	13
URZ	260 – 310	49	16
LRZ	310 – 485	74	30
Total		437	66

* The water volumes have been computed from a precise hypsometric curve, which gives the surface as a function of depth. This hypsometric curve was itself computed from a numerical 3D terrain model from Lahmeyer and Osae, which gives the lake's depth for each point on a 10 m · 10 m grid.
** The IRZ is limited from 60 to 160 m; the PRZ thickness was increased from 190 – 260 m to 160 – 260 m.

Further quantities introduced in our computations are as follows:
The calorific value of methane is 36 MJ/m^3;
The extraction efficiency is 85 % (a second evaluation will be done with an efficiency of 75 %);
The exploitation is supposed to be spread on 50 years;
Finally, the efficiency of the electrical plant, defined as the ratio of the output electrical power to the input thermal power, is 38 %.

We will estimate below the available electrical power for various scenarios.

Ideal limit case, exploiting the full methane content in the lake:
Available methane volume: 66 km^3
Corresponding thermal energy: 66 $km^3 \cdot 36$ MJ/$m^3 = 2.38 \cdot 10^{12}$ MJ
Available energy per year: $2.38 \cdot 10^{12}$ MJ / 50 year = $47.5 \cdot 10^9$ MJ/year
Available energy output from the extraction station: ($47.5 \cdot 10^9$ MJ/year) 0.85 = $40 \cdot 10^9$ MJ/year
Thermal power entered into the generator: $40 \cdot 10^9 / (365 \cdot 24 \cdot 3600) = 1281$ MW_{th}
Electrical power delivered by the electrical plant: 1281 $MW_{th} \cdot 0.38$ MW_{el} / MW_{th} = **487 MW_{el}**

With our technology, while exploiting the resource (URZ + LRZ):
Available methane volume: 46 km^3
Corresponding thermal energy: 46 $km^3 \cdot 36$ MJ/$m^3 = 1.656 \cdot 10^{12}$ MJ
Available energy per year: $1.656 \cdot 10^{12}$ MJ / 50 year = $33 \cdot 10^9$ MJ/year
Available energy output from the extraction station: ($33 \cdot 10^9$ MJ/year) · 0,85= $28 \cdot 10^9$ MJ/year

Thermal power entered into the generator: $28 \cdot 10^9$ / $(365 \cdot 24 \cdot 3600) = 892\ MW_{th}$
Electrical power delivered by the electrical plant: $892\ MW_{th} \cdot 0{,}38\ MW_{el}/MW_{th}$ = **339 MW_{el}**
The proportion of this mode to the ideal case is 339/487 = **69.6 %**.

With our technology, while exploiting the resource (URZ + LRZ) plus the potential resource PRZ:
Available methane volume: 59 km^3
Corresponding thermal energy: $59\ km^3 \cdot 36\ MJ/m^3 = 2.1 \cdot 10^{12}$ MJ
Available energy per year: $2.1 \cdot 10^{12}$ MJ / 50 year = $42 \cdot 10^9$ MJ/year
Available energy output from the extraction station: ($42 \cdot 10^9$ MJ/year) $\cdot$ 0.85 = $36 \cdot 10^9$ MJ/year
Thermal power entered into the generator: $36 \cdot 10^9$ / $(365 \cdot 24 \cdot 3600) = 1145\ MW_{th}$
Electrical power delivered by the electrical plant: $1145\ MW_{th} \cdot 0{,}38\ MW_{el}/MW_{th}$ = **435 MW_{el}**
This mode operates at 435/487 = **89.3 %** of the ideal limit.

The method exploiting the potential resource yields a power of **435 MW_{el}** instead of **339 MW_{el}**. The gain is **96 MW_{el} .**

<u>Exploiting the potential resource PRZ in addition to the resource (URZ +LRZ) gains 28 % in energy capacity during the full methane exploitation from Lake Kivu and achieves 89.3 % of the ideal exploitation limit.</u>

The exploitation as recommended by the MPs

The MPs lack an Efficiency Criterion
The omission of an efficiency criterion is surprising in a text aiming to define a sound, optimal and sustainable technique for the extraction of methane from Kivu.
An operator who uses a technology wasting 60 % of methane in the rejected water is not penalized compared to one that returns only 15 % of methane.
Moreover, an operator who consumes to operate his facilities 25 % of the electricity generated from methane extraction from its station is not penalized compared to an operator who consumes only 0.1 %.

In our opinion, the quality of a technology is essentially determined by its energetic efficiency. Most of the installations in use or under construction will spoil too much methane in the rejected waters. Simulations show that the energetic efficiency induced by the technologies that they use wouldn't reach 50 % (to be compared to the 85 % of our technology).

The MPs technology, exploiting the resource (URZ + LRZ):
We apply a maximum efficiency of 50%

Available methane volume: 46 km^3
Corresponding thermal energy: $46\ km^3 \cdot 36\ MJ/m^3 = 1.656 \cdot 10^{12}$ MJ
Available energy per year: $1{,}656 \cdot 10^{12}$ MJ / 50 year = $33 \cdot 10^9$ MJ/year
Available energy per year output from the extraction station (the energetic efficiency is supposed to be 50 %): ($33 \cdot 10^9$ MJ/year) $\cdot$ 0.50 = $16 \cdot 10^9$ MJ/year
Thermal power entered into the generator: $16 \cdot 10^9$ / $(365 \cdot 24 \cdot 3600) = 525\ MW_{th}$
Electrical power delivered by the electrical plant: $525\ MW_{th} \cdot 0{,}38\ MW_{el}/MW_{th}$ = **200 MW_{el}**
The proportion of this mode to the ideal case is 200/487 = **41 %**.

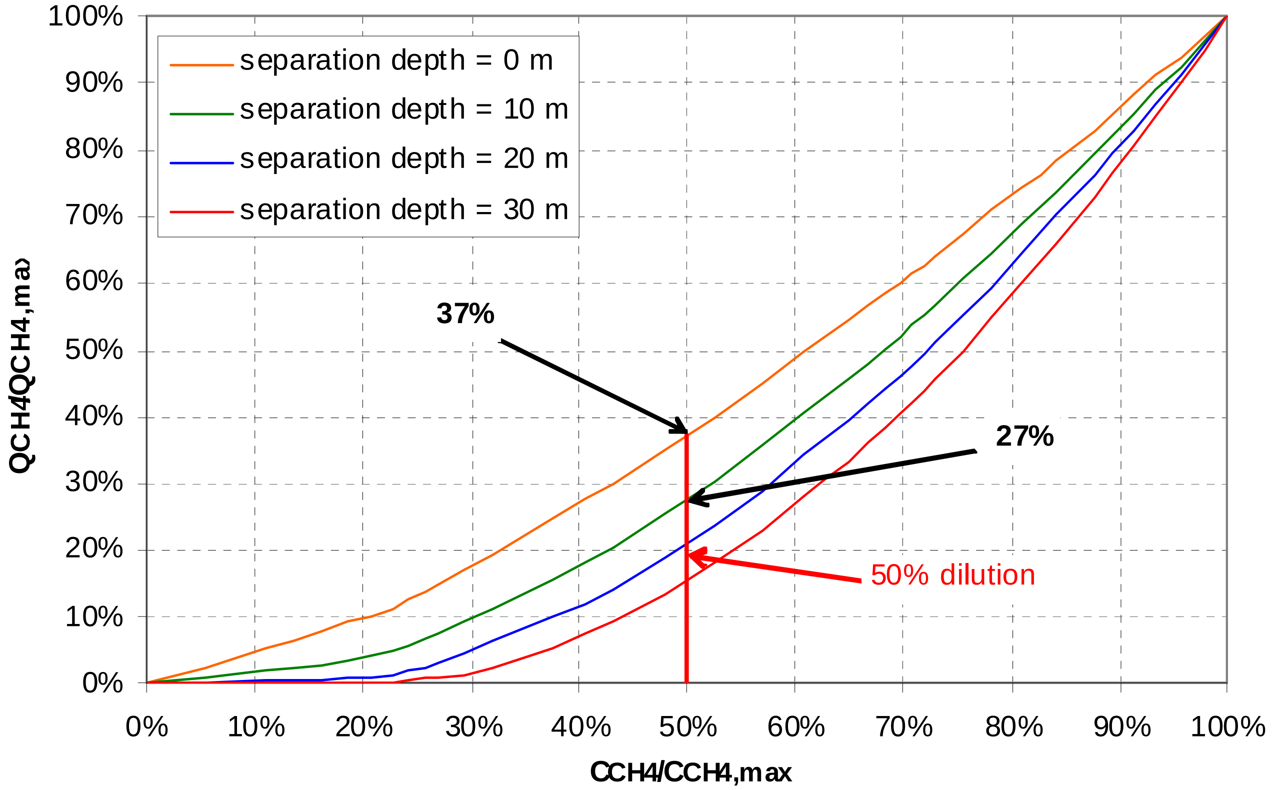
The delivered 200 MW are to be compared with the 339 MW (resp.: 430 MW) obtained with our technology when exploiting the resource alone (resp.: the resource plus the potential resource). Our technology allows producing twice more electrical power than a non optimal technique.

To sum up, the future regulation to be adopted should specify the minimal energetic efficiency value that any exploitation should obey. Controls should be done by measuring the dissolved methane concentration in the rejected waters.

Consequences of rejecting waters into the resource

In our proposition for regulation texts, downloadable from our site http://www.dataenvironnement.com/kivu2011/, we state the consequences that would be involved if degassed waters were rejected into the resource itself. Rapidly and inevitably a dilution would incur: the waters in the resource would mix with the rejected waters. The flow of extracted gas in the extraction plants would diminish, as stated in the Ylec Report "Exploitation of Lake Kivu Gas Resource : consequences of the re-injection of degassed water into the Resource Zone", September 2009, downloadable from our site. The methane flow decrease would be very detrimental
to the extraction stations : a station designed for a given power will gradually turn into a situation where it produced half the foreseen electricity.

The following quantitative plots show
- on the horizontal axis the methane concentration, relative to the concentration at origin,
- on the vertical axis the methane flow, relative to the flow at origin.



The curves show how the flow augments with the methane concentration, with various options as to how deep the separator is situated.
Consider the blue curve, corresponding to a 20 m deep separator, which is a good compromise between methane loss and an acceptable vacuum rate.
After one quarter of the resource is exploited, the methane concentration falls by 25 %, and the methane flow falls by 45 % of its original value.
After one half of the resource is exploited, the methane concentration falls by 25 %, and the methane flow falls by 80 % of its original value.

The resource will progressively lose its efficiency and become more like a potential resource.
To estimate at which stage exploiting the diluted resource stops being cost efficient necessitates economical criteria beyond our competence. But the following hints may be useful for a decision:
- when one quarter of the resource will have been exploited, the methane flow in the stations will be reduced to 55 % of its initial value.
- when half of the resource will have been exploited, the methane flow in the stations will be reduced to 20 % of its initial value.

If following the MPs' recommendation, we had estimated the exploitable power during 50 years to be 200 $MW_{el.}$ But the dilution caused by rejecting the degassed waters into the resource has the effect that only 20 to 55 % of this power will be accessible, with the inconvenience that the flow will decrease with time. The global exploitable power will hence be between 200 $MW_{el} \cdot 0{,}20 = 40\ MW_{el}$ and 200 $MW_{el} \cdot 0{,}55 = 110\ MW_{el.}$

The exploitation will achieve only between 40/487 = **8,2 %** and 110/487 = **22,6 %** of the ideal limit power.

CONCLUSION

Applying our technology allows to globaly get between 4 to 10 times more energy than with the method recommended by the MPs.