International Journal of Engineering Research and Science & Technology

IJERST

ISSN : 2319-5991
Vol. 5, No. 4
November 2016

www.ijerst.com

Email: editorijerst@gmail.com or editor@ijerst.com

Int. J. Engg. Res. & Sci. & Tech. 2016

International Journal of Engineering Research and Science & Technology

ISSN 2319-5991 www.ijerst.com
Vol. 5, No. 4, November 2016

Research Paper

IMPACT ASSESSMENT OF KALETA HYDROPOWER DAM ON KONKOURÉ WATERSHED

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Building a large structure such as a dam is never without consequences on the environment. The Kaleta dam is no exception to this rule. So we tried to see throughout this study, what could be the impact of such a dam on the quality of the reservoir water. Regarding the impact of the dam on the water quality, we came to the conclusion that there is a 60% probability that the waters of the Kaleta restraint are eutrophic. However, eutrophication can have serious consequences for the environmental and economic, from the deoxygenating of water and the production of toxic and corrosive compounds (ammonia and sulfur hydroxide and others). The retaining Kaleta however has two advantages: intake tower and a short residence time. Taking turn makes possible the rejection of an acceptable quality from water downstream by varying the water catchment level. The short residence time allows in theory a quick cleaning of the reservoir.

Keywords: Impact, Assessment, Kaleta hydropower dam, Konkoure, Watershed

INTRODUCTION

The use of hydropower in the society has a long history that started more than 2000 years ago, (Maria Steinmetz *et al.*, 2014), but according to (Layman, 1998) it has experienced that some hydroelectric facilities have been designed with a single purpose the production, and have not taken into account local site environmental data. It can then result different environmental nuisances: obstacle for the fish fauna, impact on recreational fishing, noise, etc. The environmental impact of water quality mainly focus on the source and distribution of pollutants after storing water, changes of water quality in the reservoir, the trend of eutrophication, the status of pollutant enrichment in bottom sediments, water quality of the outflows from the reservoir and downstream, (Wang *et al.*, 2012). (David Sutcliffe *et al.*, 1992) stipulates that, eutrophication is thus a global problem aggravated by contamination and other sources of pollution around the world. The consequences of the deterioration of the water bodies under eutrophication stress besides the usual and well known impacts on the

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biogeochemical and technological cycles in lakes and reservoirs are also of an economic and social nature. These are not well measured or well discussed consequences, but eutrophication has large scale impact into the economy of entire regions as well as in the social context quality of life and human, (Mendiondo, 2008). (Balcerzak, 2006) also said that, eutrophication is the process of gradual enrichment of reservoir water with plant food, mainly nitrogen and phosphorus compounds (nutrients). Water eutrophication is one of the most challenging environmental problems in the world. The increasing severity of water eutrophication has been brought to the attention of both the governments and the public in recent years. According to (Xiao Yang *et al.*, 2008), the mechanisms of water eutrophication are not fully understood, but excessive nutrient loading into surface water system is considered to be one of the major factors.

According to (Dan Lansana Kourouma *et al.*, 2005), Guinea is part of the class of the countries that are least served by electricity. His energy situation is characterized by a low level of energy consumption per capita, the importance of traditional energy sources in the energy balance, relatively heavy hydrocarbons in conventional energy and hydroelectric potential (6.1 GW) operated less than 2% (National Directorate of Environment, 2006).

Liu *et al.* (2013) mentioned also that, Guinea is suffers from a deficit of electricity for several years while she has a significant hydroelectric potential (26 000 GWh). The Republic of Guinea has adopted, since 1987, a regulatory framework on the management of natural resources and protection of the environment. The decree 990/MRNEE/90 which regulate the content, methodology and procedure for impact studies are part of the device. However, there is no regulatory text specific environmental monitoring process in Guinea, which is not conducive to public participation. There is no policy on the promotion and development of renewable energy projects in Guinea. It targets a renewable energy penetration rate of 2 to 6% in 2013 and 8 to 25% in the long term (until 2019), (Karim Samoura, 2006).

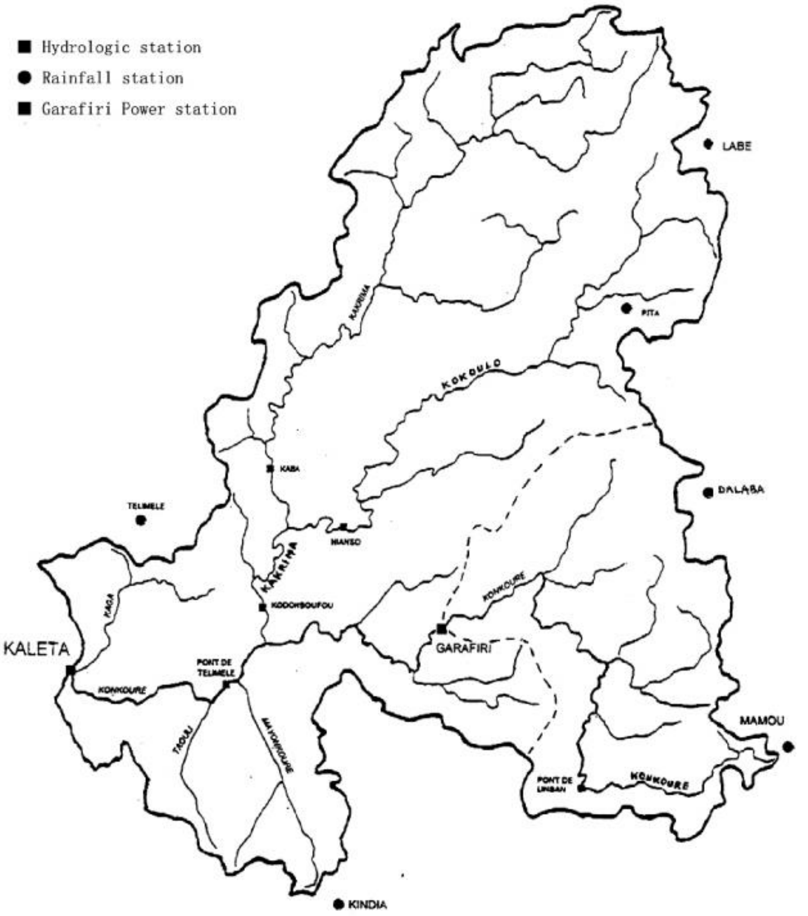
The main objective of this study is to predict what the impact of the dam on water quality Konkouré. It is therefore proposed to try to anticipate short and medium term, which may be the evolution of water quality Konkouré following the impoundment of the dam. This means assessing the risk of eutrophication than short future restraint. To do this, we will use models developed by OECD researchers (Organization for Economic Cooperation and Development based in Paris). For the application of this model we will try to estimate as accurately as possible, the amounts of total phosphorus contained in the different compartments that will be submerged by the waters of the dam which will react with the water column. Because of the difficulty in estimating a number of parameters, we limit ourselves to the consideration of the following parameters: total phosphorus in plant biomass, in the litter, in soil and brought by the river.

MATERIALS AND METHODS

Sites and Datasets

Konkouré River is one of the largest river in Guinea. It rises in the Fouta Djallon (its altitude is about 950 m). Its total length is 360 km. It covers a basin of 17.000 km^2. It flows from the northeast to the southwest (see Figure 1 below). Its main tributaries are Kaga and Kakrima river

Figure 1: The Maps of Konkoure River Watershed above Kaleta Dam Site



Note: Konkoure River covers a basin of 17.000 km^2. It flows from the northeast to the southwest. ‰. Its geographical coordinates are: latitude north 10° 27', longitude west 13° 16'. Upstream of the dam, the drainage area is 11380 km^2. At 1200 m above the dam, the Kaga tributary joins the main river right bank.

on the right bank, the river and the Taouli Badi river left bank. The Kakrima is the largest tributary, which is about half the Konkouré drainage area. In the basin, most of the hills are at an altitude of about 200-1000 m, with an average altitude of 600 m. The headwaters of Konkouré is steep, with an average of 6‰ sloping. Between Linsan and the confluence of Kakrima bridge, the slope of the river is about 1.5‰. Between the confluence of Karima and Kaleta chute, the slope averages about 1.4‰. Its geographical coordinates are: latitude north 10° 27', longitude west 13° 16'. Upstream of the dam, the drainage area is 11380 km^2. At 1200 m above the dam, the Kaga tributary joins the main river right bank. The width of the river is 200 m to about 750 m of the dam. The main course is dispersed in 5 small rivers from left to right are, Sanfokui, Franbanga, Dirty, Songo and Lekte. The total river volume about 350m downstream of the dam, forms a large group waterfalls (five waterfalls in total), and Songo Lekte are the two largest river arms, falling water is about 40 m high.

Table 1 displays some hydrological data of Konkoure River which can be used to calculate

Table 1: Changes in the Capacity of Possible Water (from EDF-Coyne and Belller)

Capacity of the Water	Normal Elevation (350 m)	Minimal Elevation (328 m)	Maximal Elevation (353 m)
Lake area (km^2)	91	31	97
Capacity (hm^3)	1620	322	1900

Table 2: Monthly Flow Characteristics Konkouré to Kaleta During the Period from 1948 to 2002 in m^3/s (According Hydroconsult International, 2003)

	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Ave.	12.4	6.9	2.8	1.4	1.5	9.9	82.2	266.0	331.0	138.0	62.5	25.2	70.9
Max.	25.4	15.8	6.1	7.1	4.6	19.8	189.0	485.0	401.0	299.0	127.0	52.6	114.0
Min.	6.7	6.7	0.5	0.1	0.2	2.5	38.4	106.0	110.0	57.2	28.2	14.2	40.1

the average depth (Z) of the restraint which is given by the following formula:

$Z = V_0/A_0$

V_0 = the volume of the lake to its average rating;

A_0 = lake area to the same rating

The average depth is about 18 m.

ORSTOM has made since 2000 many steps along the hydrometric Konkouré especially downstream of Kaleta dam site. Meteorological stations are read either by local observers, or they are equipped with automatic platform with PH11 ARGOS. This is the case of Kaleta station. Observations on Kaleta station are thus fairly comprehensive and of good quality (Table 2).

Using these data, we can draw Konkouré hydrogramme at the site Kaleta which gives us a more vivid picture of local hydrological conditions.

From the hydrogram presented in Figure 2, we see that much of the rainfall occurs during a short period from July to October. The module (average annual rate) is 70.9 m^3/s which represent an average annual intake of 2238 hm^3 water. We can then calculate the average residence time of water T(W) from the following formula:

$T(W) = V_0/Q_y$

V_0 is the volume of the reservoir to its normal dimension (1620 hm^3);

Q_y is the average annual outflow of the lake (2238 hm^3)

In this case, the reservoir will have a 0.72 year residence time. That is to say that will renew its waters about 1.4 times per year and that the water will stay in the tank approximately 8.7 months. This is a very important factor because it will determine in part the quality of the lake: a short residence time will induce movement of nutrients and clean the quick restraint, which minimizes the risk of eutrophication in restraint.

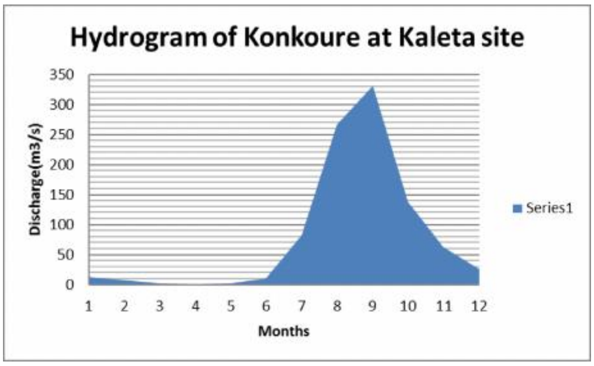
Hydrochemical data are very few. BCEOM (2010), however, conducted a number of analyzes with the following results:

- PH: 6.2
- Nitrate (NO_3): 6.1 mg/l
- Conductivity: 40 μS/cm
- Phosphate (PO_4^3) <0, 1 mg/l

The Konkouré waters are slightly acidic, weakly mineralized and have a phosphorus deficiency.

The study of the evolution of the water quality is intimately related to the understanding of

Figure 2: Konkouré Hydrogramme at the Kaleta Dam Site



Note: Hydrograph obtained by plotting meteorological data of Konkoure River. It gives additional information about the local hydrological condition of the watershed.

decomposition of organic matter. To study the evolution and assess the impact of Kaleta dam on water quality Konkouré we will use models developed in 1982 by the OECD (Organization for Economic Co-Operation and Development) researchers. These are designed to help better quantify the relationship between the nutrient load of the water (especially phosphorus) and their trophic reaction.

Presentation of the Organization for Economic Co-Operation and Development (OECD) Models

The OECD program on eutrophication has enabled the creation of predictive models of water quality. They rely on data collected at four regional projects (study of 150 lakes and reservoirs, all in temperate areas) covering a wide range of climatic conditions. One of these projects has also been devoted to the study of reservoirs and artificial lakes, which allows us to justify the use of these models, both for natural lakes for artificial reservoirs “case of the reservoir Kaleta” (Victor Afonso, 2002). The question that is legitimate to ask is: these models are applicable to tropical regions, while water bodies that have been studied for the realization of these models are in temperate regions?

It is true that there are significant differences between the regions of lakes and reservoirs those temperate and tropical regions. Their annual temperature is higher (about 25 °C against 10 to 15 °C). There is no freeze and thaw cycle in the tropics, which allows a continuous plant biomass production throughout the year and therefore lake productivity and higher tropical reservoirs than temperate waters. Moreover, unlike in temperate regions where phosphorus is often the limiting factor for the development of phytoplankton is generally nitrogen that plays this role in the intertropical regions.

Despite these differences in functional, (Thornton and Walmsley, 1982), observed that these types of models, based on phosphorus flows seem to be adapted to the lakes and reservoirs of tropical environments because the distinction between these two types of ecosystems is based primarily on quantitative and temporal differences rather than qualitative. Such models can therefore be used as valuable tools for forecasting for the case of dam Kaleta. Subsequent monitoring of water quality (over 4 years), will judge their relevance.

Elaboration of Models

In general, a lake is an open system. One can describe the behavior of the system from a conventional the mass balance equation, which calculates the change in mass of material accumulated in a lake during a time interval “t (assumed to be 1 year in the report conducted by OECD).

$$\frac{\Delta M_{\lambda}}{\Delta t} = (Q_i[\overline{M}]_i) - \Sigma(Q_{\omega}[\overline{M}]_{\grave{u}}) - A_eF_e\,(M) + A_sF_s\,(M) \qquad \ldots(1)$$

$\frac{\Delta M_\lambda}{\Delta t}$ = the mass balance during the period t of matter M in a lake λ;

Q_i = volume of the incoming stream i (m^3/s);

$[\overline{M}]_i$ = average concentration of the incoming stream in (mg/m^3) in M;

Q_ω = stream volume evacuated ω (m^3/s);

$[\overline{M}]_\omega$ = concentration of the stream evacuated ω (mg/m^3) in matters M;

A_e and A_s = respective surfaces of the hypolimnion and sediment;

$F_e(M)$ and $F_s(M)$ = positive and negative flow of matters M, through these surfaces ($mg/m^2/s$).

However, our inability to accurately measure each term requires us to make certain assumptions and simplifications that I will outline later. After simplification of different processes, the OECD researchers were able to define an empirical equation which connects the phosphorus concentration of arrival water and that of the lake, this by taking into account the residence time of the water.

$$[\bar{P}]_\lambda = 1.55 \{[\bar{P}]_E / (1+\sqrt{TS})\}^{0.82} \quad ...(2)$$

$[\bar{P}]_\lambda$ = annual average concentration of total phosphorus in the lake (mg/m^3);

$[\bar{P}]_E$ = average concentration of phosphorus in annual fluid intake (mg/m^3) which equals:

Lp/Qs;

Lp = annual phosphorus load per unit area in a year = specific load per unit area of Ao restraint (mg/m^2/an);

Q_s = specific discharge = coefficient renewal * average depth (m/year);

TS = water stay time (year).

RESULTS OF THE APPLICATION OF THE OECD MODELS

The following diagram (Figure 3) provides a synthesis of the types-equations developed by OECD and guidance on probable trophic category of restraint.

From this diagram, we can provide short-term (one year) the qualitative characteristics of the future reservoir (trophic categories). But it is even more appropriate to define the characteristics of the reservoir in probabilistic terms. This is why the OECD researchers have developed a simple graphical interpretation (see Figure 4) to define the probability that a lake be in each of the following trophic categories:

- Ultra-oligotrophic (very low nutrient water);
- Oligotrophic (low nutrient water);
- Mesotrophic (average nutrient content);
- Eutrophic (high nutrient content in water);

Figure 3: Diagram Illustrating the Relationship Between the Annual Average Phosphorus Concentration in the Waves Entering the Restraint $[\bar{P}]_E$, the Expected Annual Average Concentration of the Lake $[\bar{P}]_\lambda$ and the Residence Time T(w) (Vollenweider and Kerekes, 1982; Updated, 2015)

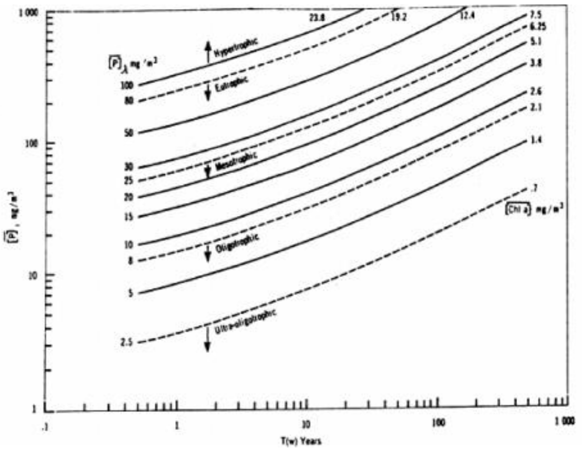
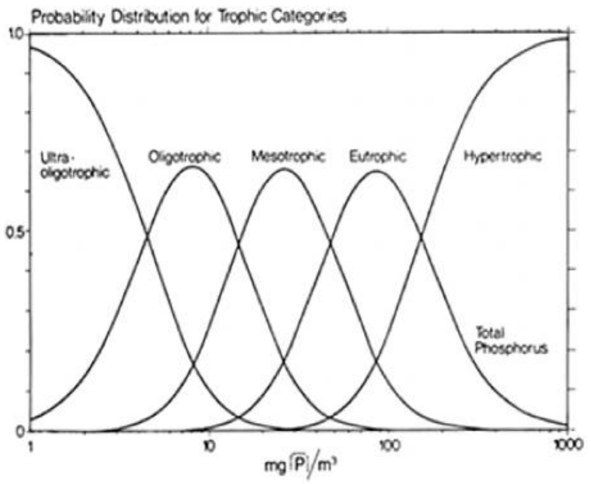


Figure 4: Probable Distribution of Different Trophic Categories Depending on the Annual Average Concentration of P-Total Lake Water Based on Vollenweider and Kerekes (1982) Updated (2015)



- Hypertrophic (very high content of nutrients in water).

Application of Models in Case of Dam Kaleta

So we have to find a possible match between the case Kaleta and models in order to apply them. To do this, we propose to proceed as follows: consider that the continuous supply of phosphorus from the internal load (degradation of plant biomass and progressive release of soil) is comparable to a river intake. We can then say that the average concentration of phosphorus in different waves $[\bar{P}]_T$ equals:

$$[\bar{P}]_T = [\bar{P}]_E + [\bar{P}]_1 \quad ...(3)$$

In this relation, $[\bar{P}]_E$ represents the average concentration of phosphorus water arrival (river inputs) and $[\bar{P}]_1$ represents the average concentration of phosphorus flow from the internal load (degradation of organic matter and soils). Now we will see later that $[P]_E = 0$. Thus we get the following equation:

$$[\bar{P}]_T = [\bar{P}]_1 \quad ...(4)$$

To use the OECD model so we will have to make a modification of the equation (2)

$$[\bar{P}]_\lambda = 1.55\ \{[\bar{P}]_1/(1+\sqrt{TS})\}^{0.82} \quad ...(5)$$

Hence the interest:

1. An estimate of the amount of phosphorus that will be submerged by the future reservoir, more just and most relevant possible;
2. A correct estimate of the decomposition rate of organic matter, and release of phosphorus in the various compartments in the first year after impoundment.

To quantify the better the total P, we proceed to a division into several compartments of the total area of watershed concerned by the restraint:

Compartment 1: Deforested area before impoundment (about 700 ha);

Segment 2: Area that could be described as "natural" and is composed of gallery forest, the clear savanna and grassland (approximately 8500 ha);

Compartment 3: The river upstream.

It is therefore to quantify each of the three compartments of the amount brought phosphorus. I call PT1 phosphorus brought by the first compartment; PT2 phosphorus brought by second compartment... The total amount of phosphorus that will be submerged in the reservoir (PTR) will be equal to:

PTR = PT1 + PT2 + PT3

where:

PT1 = phosphorus vegetation following a regeneration (PVR) + phosphorus released by the soils of the deforested area (PSD).

PT2 = phosphorus from the decomposition of plant biomass (we do not take into account the animal biomass due to the lack of reliable data) of gallery forest (PDF).

+ Phosphorus from the decomposition of plant biomass in the savanna (PDA).

+ Phosphorus from the decomposition of plant biomass of grassland (PDH).

+ Phosphorus from the decomposition of litter (PDL)

+ Phosphorus leached from soil (PS).

PT3 = phosphorus supplied by rivers (PCE)

Hence the final equation:

PTR = [(PVR + PSD) + (PDF + PDH + PDL + PS) + PCE]

In this formula, we do not take into account the flow of phosphorus leaving because this data will be taken into account in models that can later employ considering the time of stay.

RESULTS AND DISCUTION

After all calculations we have obtained the following results:

PT1 = 14.017

PT2 = 184.093

PT3 = 0

So PTR = 14.017 + 184.093 + 0

PTR = 198.110 t phosphorus brought in total

So we could determine what will be the phosphorus input in the water column during the first year after impoundment $[\bar{P}]_1$. Can now be calculated, i.e., the average concentration of phosphorus flow through internal gains (degradation of organic matter and soil) from the following formula:

$[\bar{P}]_1$ = Lp/Qs

with:

Lp = Annual phosphorus inputs per unit area in a year

= Specific load per unit area of the retaining Ao (mg/m^2/year)

= 198110 * $10^6/9*10^7$ = 2201.22 mg/m^2/year

Q_s = Specific speed (m/year) = coefficient of renewal * average depth;

= 0.714 * 18 = 12.86 m/year

where $[\bar{P}]_1$ = 171.17 mg/m^3

To finally know the average concentration of the lake, we will use the equation

$$[\bar{P}]_\lambda = 1.55\{[\bar{P}]_1/(1+\sqrt{TS})\}^{0.82}$$

$$[\bar{P}]_\lambda = 1.55\ [171.17\ (1+\sqrt{0.72})^{0.82}$$

$$[\bar{P}]_\lambda = 63.53 \text{ mg/m}^3$$

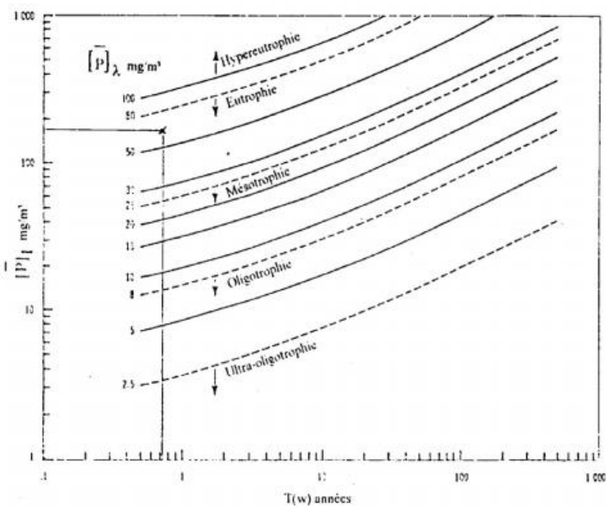
Synthesis of Results

The most important result of this study, which will serve us for the interpretation of results, is $[\bar{P}]_\lambda$. In fact using this data we will see what will be, according to the OECD study models the trophic level of the future reservoir.

We have the following data: $[\bar{P}]_\lambda$ = 63.53 mg/m^3 and T(w) = 0.72 year

According to the intersection of these two data diagram above (Figure 5), we can deduce that the tendencies of water for future restraint Kaleta will eutrophication. We can also express this trend in probabilistic terms (see Figure 6). This in my opinion seems more fitting.

Figure 5: Synthesis Diagram from Types Equations Developed by OECD to Express the Trophic Category of a Lake Depending on Various Parameters Such as the Average Annual Concentration of Lake Waters and the Average Stay Time



We can read in this figure the probability that have Kaleta waters to be in each trophic category. This gives us the following results:

60% chance to be situated in the eutrophic category;

30% chance to be situated in the mesotrophic category;

10% chance to be situated in the hypertrophic category;

H" 0% chance to be situated in the oligotrophic category.

According to the OECD model, it is unlikely that the lake waters are oligotrophic (H" 0%) and unlikely to be hypertrophic (10%). However as regards the other two categories, the probability is higher, with a maximum probability for the event "eutrophic waters" (60%). It should be noted that this result is valid only during the time period considered in this study, which is to say during the first year after impoundment.

CONCLUSION

Building a large structure such as a dam is never without consequences on the environment. The Kaleta dam is no exception to this rule. So we tried to see throughout this study, what could be the impact of such a dam on the quality of the reservoir water.

After many calculations and by using models developed by the OECD, we came to the conclusion that there is 60% probability that the water of the retaining Kaleta is eutrophic. However, eutrophication can have serious consequences for the environmental and economic, of the deoxygenation of water and the production of toxic and corrosive compounds (ammonia and sulfur hydroxide and others).

The retaining Kaleta however has two advantages: an intake tower and a short residence time. The tower making it possible rejection of acceptable quality water downstream by varying the water capture level. The short residence time allows in theory a quick cleaning of the reservoir. Nevertheless, the particular form of the future retaining Kaleta (dendritic) can counteract the latter point. The eutrophication process is not simple to grasp by the many parameters involved in this process. In any case, it is preferable from an ecological and economic point of view, to try to influence these parameters before the eutrophication process of is being established.

ACKNOWLEDGMENT

The authors are grateful to the reviewers especially Ruben Gebdang for his reading of the manuscript, and for his suggestions and critical comments.

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ISSN 2319-5991
04
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