Tutor/s
Dr. Alexandra Elena Plesu Popescu
Sr. Yen Keong Cheah
Departament d'Enginyeria Química i Química Analítica

Grau en Enginyeria Química

Treball Final de Grau

Eco-gamma Assessment on Water Resources Impact

Isaac Cruz Simarro

September 2021

UNIVERSITAT DE BARCELONA

Llegará un momento en que creas que todo ha terminado.
Ese será el principio.

Epicuro

En primer lloc m'agradaria donar les gràcies a tots i cadascun dels professors del Grau d'Enginyeria Química, sense ells i la seva implicació arribar fins aquí no hagués sigut possible. En aquest cas, agrair també a la Dra. Alexandra i el Sr. Keong, que tot i les dificultats, incloses les meves, sempre han tingut temps per ajudar-me i comentar les coses. En particular m'agradaria mencionar al Dr. Bonet, qui em va rebre a primer com a tutorat, i m'ha guiat durant aquests anys per finalitzar el grau.

Recordar també als amics, tant aquells que son de tota la vida, com aquells que es coneixen durant l'etapa universitària i en molts moment es converteixen en inseparables. Gràcies per tots els meravellosos moments que m'heu donat.

I per últim, i possiblement els més importants, la família. Els que m'han recolzat en tots moments, en les bones i les dolentes, i m'han animat a seguir endavant , sense ells, sens dubte, no seria aquí.

Moltes gràcies a tots,

Ens veiem aviat!

CONTENTS

SUMMARY

Nowadays, the environmental impact of the water usage is estimated based on the amount of water consumed, but it does not consider the quality of the water. Although, there are different methods to quantify the water footprint, the amount of water consumed, there is not a method which can determinate the water quality impact evaluation. The aim of this project is the validation of a novel index that measures the environmental impact of water degradation. This index explains, not only the quantity of water but the impact of human or natural pollution

No other articles or projects evaluate the ecological impact by using the eco-gamma equation, and especially focusing on water degradation.

Real examples have been searched, to give the evaluation a realistic condition, and evaluate different scenarios in different conditions. Also trying to implement the use of this equation for other uses, how can it be the simulation of the impact of an industrial activity in a certain environment.

From energy and mass balances, and this easy eco-gamma equation which evaluates how different parameters affect the growing rate of different species, it is possible to evaluate the impact different activities make to an environment.

Keywords: Environmental impact, systems ecology, resources conservation.

RESUM

Actualment, l'impacte ambiental de l'ús de l'aigua s'estima en funció de la quantitat d'aigua consumida, però no té en compte la qualitat de l'aigua. Tot i que hi ha diferents mètodes per quantificar la petjada hídrica, la quantitat d'aigua consumida, no hi ha un mètode que pugui determinar l'avaluació de l'impacte sobre la qualitat de l'aigua. L'objectiu d'aquest projecte és la validació d'un nou índex que mesuri l'impacte ambiental de la degradació de l'aigua. Aquest índex explica no només la quantitat d'aigua, sinó l'impacte de la contaminació humana o natural.

Cap altre article o projecte avalua l'impacte ecològic mitjançant l'equació eco-gamma, i centrant-se, sobretot en la degradació de l'aigua.

S'han buscat exemples reals per donar a l'avaluació una condició realista i avaluar diferents escenaris en diferents condicions. També intentant implementar l'ús d'aquesta equació per a altres usos, com pot ser la simulació de l'impacte d'una activitat industrial en un entorn determinat.

A partir dels balanços de matèria i energia, i aquesta fàcil equació, eco-gamma, que avalua com diferents paràmetres afecten la taxa de creixement de diferents espècies, és possible avaluar l'impacte de les diferents activitats en un entorn determinat.

Paraules clau: Impacte ambiental, ecologia de sistemes, conservació de recursos.

1. INTRODUCTION

Some methods such as the exergy is a recognized useful variable to assess the environmental impact due to the deviation of variables in the system from a reference state, but it does not consider the degradation and toxicity effect on the water. It considers the sources collected from the environment to the process and the resources lost from the process, but it does not study the effect of the water streams on the local living beings. To determine the growing rate of living organisms under certain condition in a local surface, the gamma concept is proposed. Gamma method analysis the growth rate of living forms and their behaviour when water conditions change because natural and especially human life. The parameters that affect the growing rate of the species are the variation of temperature, pH, composition, acidification, toxicity, eutrophication, among other parameters that can interfere. It also must be considered that in some cases, the variation of this parameters can be favourable because it can increase the number of living beings, but it affects others which were adapted to these environmental conditions before the human impact.

Thus, the gamma concept, used as an environmental indicator, determines the effect of each set of environmental conditions to a single parameter: The growing rate of the adapted specimens adapted to a certain ecosystem. It must be applied at a local scale to not suffer the dilution effect that would be considered if it is applied globally.

1.1. **WATER POLLUTION**

The release of substances into bodies of water degrading its quality and rendering it toxic to humans or the environment is considered as water pollution. As water can dissolve more substances than any other liquid, it is the reason why toxic substances from human uses get dissolved and causing this pollution.

This water pollution is, of course, extremely dangerous to human lives, as it causes more than 1.5-million-year deaths and about 1 billion people sickens due to consume this water (NRDC

Foundation). In the other hand it cannot be forgotten the significant effect this produces to the ecosystems, as they rely on a complex network of animals, plants, bacteria, and fungi, which interact each other. When some of these parts of the environment is affected, can create a chain effect, endangering a whole aquatic system.

There are many pollutants to list them all, but the most important ones are: organic, inorganic, and radioactive. It is possible to divide the main categories of water pollution:

-Groundwater: This type of pollution is a mix between natural and human contamination, of course, without human effect it would not exist. When rain falls, it seeps into the earth, filling the cracks and porous and becoming groundwater. This groundwater it is extremely important to some areas around the world, as it is the unique freshwater source. When this rain seeps in contaminated areas, gets polluted from pesticides and fertilizers, producing an important environmental impact. This is nearly impossible to eliminate, or at list, expensive. This groundwater can also flow into rivers and lakes spreading the pollution.

-Surface water: The biggest amount of water on the earth, the one that fills oceans, lakes, and rivers. On that case, ocean water is not considered as freshwater, so it is going to be only considered the river and lakes water. From this amount of water, around half of the rivers and a third part of the lakes are polluted (NRDC Foundation). Here, municipal, and industrial waste, as well as farm waste and fertilizers become the most important pollutants.

-Ocean water: Not considered as freshwater for human life, but the biggest ecological system in the world, is specifically polluted by chemicals and nutrients, and particularly plastic travel around the oceans. Also spoiled by oil spills that destroys the aquatic life.

There are also some different types of pollution sources, which divide in next sections:

-Nonpoint source: this type of pollution is derived from different sources. Is difficult to regulate and identify a guilty, as this ranges from agricultural pollution to stormwater runoffs.

-Point source: One of the most important categories, which includes a unique point of pollution. This point can be legal or illegal, and can come from manufacturers, refinery, illegal dumping, chemical and oil spills, among many others. On that case there are regulations that establish the limits on what can be discharged directly into a body ow water.

1.2. **CAUSES OF WATER POLLUTION**

Due to the big amount of water used by industry, and farming sectors they are one of the biggest sources of water contamination. This contamination can come from carrying away the waste from the plant, refrigerating the cooling towers or many other activities where water is used. This is one of the reasons why there are many causes of water pollution. Eco-gamma equation, allows to use a big range of parameters (1.3.2), and many of them are highly affected by the next pollutants:

- Mercury: A metallic element. As it is non-biodegradable substance, it is hard to clean from environment, so that cause important problems. Its use is hardly regulated by the authorities, and when it is used in the industry is controlled and restricted in security areas. The use of mercury has been reduced to the public (for example thermometers), due to the danger of the substance.

-Nitrates and phosphates: The use of fertilisers is increasing, so that means that nitrates and phosphates are usually being washed from soil into rivers and lakes, which can cause an environmental enrichment in nutrients, that turns in a eutrophication. This could be seen as a positive point, but it is quite the opposite, as causes phytoplankton to grow much faster, turning into an algal bloom, that may use lot of oxygen leaving none of it for the rest of aquatic life.

-Oils: Sometimes happen oil waterfalls, and usually in petrochemical plants, which does not dissolve in water. When this happens, a thick layer is formed on the water surface, and this can stop marine plants from receiving sun light necessary for the photosynthesis which produces an oxygen degradation on the area. Is not only harmful for the plants, also for the plankton and the species that feeds from these organisms. Birds are also affected as their get intoxicated and wings get filled with oil and they con not fly anymore.

Figure 1: Birds full of fuel-oil (WordPress.com, 2021)

-Pesticides: The use of pesticides is increasing time by time, used to control insects and weeds. This sometimes can run-off and can cause an important environmental impact by damaging the aquatic life.

-Nuclear waste: It comes from processes that uses radioactive technology or materials, such as medical or scientific industries.

-Sewage and wastewater: It come from our showers, sinks and from commercial, agricultural, and industrial activities. This waste contains substances such as metals, solvents, and toxic sludge, which danger seriously the systems ecology.

1.3. **ECO-GAMMA CONCEPT**

The gamma concept was initially used in the food sector. Used to describe the evolution of Salmonella during the fabrication process of dried sausages. (Coroller et al. 2015)

From this basic, an environmental impact index was proposed, the eco-gamma, mathematically represented by this equation (1):

$$\mu_{max} = \mu_{opt} \prod_{i=1}^{r} \gamma_i(X_i) \quad (1)$$

Where μopt is the optimal growth rate (T^{-1}), and μmax is the maximum growth rate (T^{-1}) at a certain value of *γ*. In expression (1), $\gamma_i(X_i)$, is the numerical number of a gamma coefficient *i* for a variable X_i, from a total of *r* variables considered. (Quezada, 2020)

However, this equation interest is not for the growing rate but the effect of the environmental variations on a determinate rate. Then equation (2) is developed from gamma traditional equation:

$$\gamma(X) = \frac{(X - X_{max})(X - X_{min})^n}{(X_{opt} - X_{min})^{n-1}\left[(X_{opt} - X_{min})(X - X_{opt}) - (X_{opt} - X_{max})\left((n-1)X_{opt} + X_{min} - nX\right)\right]}$$

This equation is valid for any X parameter, e.g. temperature, pH, NaCl content, etc. X is the parameter after the human effect, X_{opt} is the average parameter value on the environment without the human effect and X_{min} and X_{max} are the usual variations on the environment.

When all the coefficients are at their optimal value, which is the value without the human interaction, the value gamma is 1, which means that there is no impact produced. Next Table 1 provides a classification according to the values of gamma and the impact produced (Quezada, 2021

Table 1: Environmental impact categories

Gamma Value	Environmental Impact
1-0.99	Negligible
0.99-0.97	Very Low
0.97-0.95	Low
0.95-0.9	Moderate
0.9-0.8	High

0.8-0.5	Very high
0.5-0	Extremely high
<0	Death

1.3.1. Applications

As this is a very useful equation to measure local pollution, one of the biggest applications could be in the industrial sector, where each day more and more laws and restrictions are made in favor to prevent pollution. It could be interesting both for factories or chemical plants that use river or lake water in their process to control the level of pollution they are reaching, or for the authorities to measure if these industries are accomplishing these laws and restrictions.

Another interesting use is to design new projects and see if a, for example, a new industry could affect or not in a certain place.

1.3.2. Parameters

This equation can be applied in lot of different circumstances and, as well, lot of different parameters. The following parameters could be considered as the most important ones and the most useful for this equation, but there are many others that could be used and evaluated to see how a parameter can affect an ecological system.

-Temperature: The water temperature is one of the most important when considering water quality. Not only about its own effects, but temperature has a several influence among many other parameters.

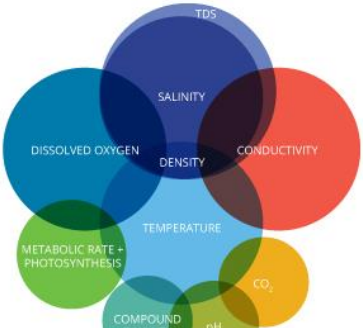

Figure 2: Temeperature effect among other parameters (fondriest.com, 2021)

Studies have shown a direct relationship between metabolic raise and temperature, as for example, some aquatic plants need warmer temperatures to grow better, while some fishes need coldest streams. (fondriest.com)

Also, high temperature in water can increase solubility, making other substances easier to dissolve and made the ecosystem even more toxic.

Water temperature can be affected by many conditions, the most important one, the sunlight. Other elements that can affect on the temperature are the atmosphere or water turbidity. This are of course, natural effects, but nowadays, human influences are the ones that mostly affect on water temperature.

During the whole year, temperature is not the same, especially on rivers and streams, which are affected by atmospheric temperature and industrial activities, and that makes species living in it have a greater resistance in front of temperature fluctuations.

-pH: If the pH of the water is too high or too low, aquatic organisms die. It is also a parameter that can affect some others, like solubility and toxicity. The factors that influence the pH are both natural, and human-made. One of the most commons causers of acidity on water is CO_2, so it is important to consider this parameter when evaluating pH impact.

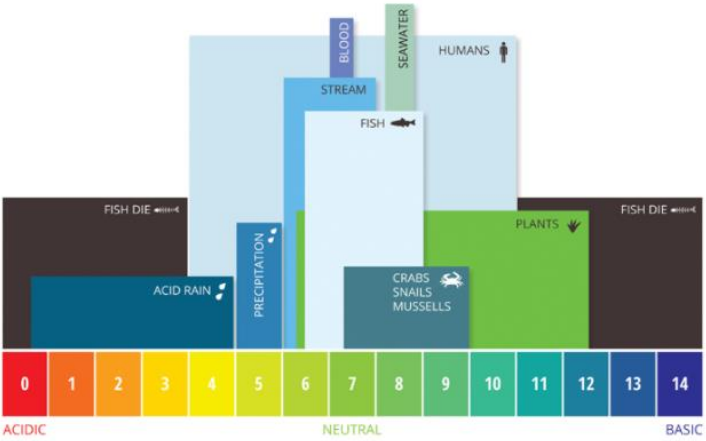

Figure 3: Optimum pH levels (fondriest.com, 2021)

pH levels vary due to environmental influences alkalinity, which changes due to the presence of carbonates and dissolved salts. Acidity of the surrounding environment can also affect the pH of the water, especially if farming or industry activities are near. The recommended pH for most of the fish is between 6.0 and 9.0, even thought, there are many scenarios and animals, and organisms get used at many different levels.

Low pH levels can increase the metals solubility, as this tends to make the water more susceptible to toxic substances.

-Dissolved oxygen: This parameter refers to the quantity of non-compound oxygen present in water, which means the oxygen that is not bonded with any other element. This is an important parameter, as its influence is vital to organisms live, many of them use this oxygen in respiration. This dissolved oxygen enters to the water by the air, slowly diffusing across the water surface, or as a pant byproduct, via the photosynthesis reaction (3). Of cause in controlled areas this can be manipulated by human action.

$$CO_2 + H_2O \quad (CH_2O) + O_2 \tag{3}$$

Oxygen solubility is directly affected by a temperature increase, also with high salt levels, so when evaluating both of this parameters, dissolved oxygen must be also in account.

The level of oxygen required for the species also depends on the type of species, since bacteria which needs low DO levels, to salmons and trout which need high levels of DO. During the pass of the years, species have adapted to low DO levels, so die rates have decreased. One of the most critical activities for the DO are the zones with a high agriculture area.

-Salinity: This is the parameter that measures the content of salt in water, as they are highly soluble and can be transported with water movement. Salt does not only affect to the ecological systems, but it does also affect infrastructures ang agriculture. The salt concertation is usually measured by the water conductivity. High salinity levels can result in a poor health or death of vegetations well as fauna, leading to a potential salt-resistant species and altering the ecological systems.

This salinity takes only important values in oceans and determinate areas, while river, streams and lakes does not important consideration to this parameter. This low consideration is reflected

on species habiting in these areas does not have a big salinity resistance range, which makes them very vulnerable in any little fluctuation.

-Water turbidity: Turbidity is an optical determination of water clarity. This is caused by suspended solids and dissolved colored materials that reduce water clarity. The opaquer is the water, the less sunlight dues enter across the surface, which implies a reduction of the photosynthetic activity of algae and plants, this makes oxygen levels decrease, affecting the aquatic life of the ecosystem. Salinity does also affect to water turbidity, as salt ions collect suspended particles and join them increasing the turbidity. Dissolved metals can attach to suspended particles and enter to the water.

These may be the most important parameters, as they are the most common ones and are the ones that usually contaminate water the most. Other parameters can affect, as in some point practically all the parameters are related one with each other.

2. OBJECTIVES

The aim of this project is the validation of a novel index that measures the environmental impact of water quality degradation. The proposal of this novel index is due to the necessity of explain not only the quantity of water but the impact of human or natural pollution.

Look for real examples where this index could be useful and see the impact that humans make to ecological systems.

Look also for new uses to this equation by searching simulation processes that use water in their plant and simulate the impact this industry would cause in a certain environment.

3. RESULTS

In the following points, results are shown. Mass balance have been solved as well as application of the eco-gamma equation. Examples have been extracted from real bibliographical information

3.1. **NALÓN RIVER**

A national real example comes from Asturias, in Spain. Here it is located the Nalón River, where the Coordinadora Ecoloxista d'Asturies expressed their refusal to the water exploitation from GENSA, an energy generating company that use the river water to refrigerate their combined cycle power plant. They plead on the big rise in temperature the company would produce to the river, generating some troubles to the river such as:

-Oxygen reduction while decreasing the oxygen solubility on the river.

-Some microorganisms or species disappearance due to the lack of oxygen.

-Growth cycle variation related with the temperature increase.

-Anormal reproduction of the cold-water species, like trout and salmon.

In this type of refrigerating processes, an important amount of water is not retouring to the river, as in some points surpass the 100ºC and turns to steam. According to the data provided by the Coordinadora Ecoloxista d'Asturies, after a study, around half of the water taken from the river is returned to the river. The water is only used as a refrigerator, so the only changes it suffers it is on temperature, not on pH, nutrients or other aspects that can be considered in the gamma method.

GENSA considers as "little significant" the amount of water caught from the river, as it reaches around 839 m^3/h. It cannot be considered in this study the effects that other industries cause to the river, such as temperature variation, treated or wastewater, as this information is not available.

The case is going to be studied in three different scenarios: (Confederación Hidrográfica del Cantábrico)

Table 2: Flowrates Nalón River

	Wet Season	Dry Season	Average annual
Flow (m^3/h)	304,200	112,464	198.648
Temperature (ºC)	7-9	25-28	13,5

All the data were provided by the Coordinadora Ecoloxista d'Asturies, so no information have been omitted on this case. With all these information's mass balance were calculated to obtain the temperature of the river after the refrigeration process, which was the only ungiven information. On this case, both, source, and receiver, are the same river.

For the eco-gamma evaluation is a perfect example, as maximum and minimums values are given, so the results can be close to real conditions. This study is focused on local impact, so it is possible to evaluate the future of species and microorganisms who live on the area.

GENSA guarantees that the thermal jump is within the legal framework, as they return the water to the river at 33ºC, only surpassing the maximum temperature by 1ºC, while the maximum temperature of the river, during the dry and hot season is around 27ºC. (Pontigo, 2009)

3.1.1. AVERAGE ANNUAL

This flow and temperature are not an average between dry and wet season, but an average value taken day per day of every registered data.

In Table 3 a summary of the data used to solve the mass balance and found the remaining information. In Table 4 the results obtained by applying the eco-gamma evaluation. (Pontigo, 2009)

Table 3: Mass balance data

Type of parameter	Parameter	Value
Global parameters	T_{max}	28 ºC
	T_{min}	7 ºC
	T_{opt}	13.8 ºC
Affluent parameters	$T_{affluent}$	13.58 ºC
	$W_{affluent}$	198,648 m^3/h
Receiver parameters	$T_{receiver}$	13.58 ºC
	$W_{receiver}$	198,229 m^3/h

Table 4: Eco-gamma evaluation

Receiver parameters	$T_{receiver}$	13.62 ºC
Global	$\gamma(T)$	1.00

The eco-gamma evaluation is 1,00, which falls in the category of Negligible Impact. This does, that the proposal from Coordinadora Ecoloxista d'Asturies of denying the exploitation of water from the Nalón River by GENSA, gets no sense, at list, for the information given and used for the eco-gamma estimation. The results, shows that as GENSA said a "little significant" amount of water taken to the river come true once the results are shown.

3.1.2. DRY SEASON

This could be the most critical season, and where the impact could increase due to the decrease of the Nalón River flow. At the same time, is also the season where the river temperature is the highest, so the temperature variation when water retouring to the river is not as big as the previous example. Therefore, is considered 28 ºC as the river temperature and the optimal temperature as it is supposed that the species that habit the river are used to this temperature. A new eco-gamma evaluation is done, and the results are exposed in Table 6. (Pontigo, 2009)

Table 5: Dry season eco gamma data

Type of parameter	Parameter	Value
Global parameters	T_{max}	28 ºC
	T_{min}	7 ºC
	T_{opt}	28 ºC
Affluent parameters	$T_{affluent}$	28 ºC
	$W_{affluent}$	112,464 m^3/h
Receiver parameters	$T_{receiver}$	28 ºC
	$W_{receiver}$	112,045 m^3/h

Table 6: Dry season eco-gamma evaluation

Receiver parameters	$T_{receiver}$	28.01 ºC
Global	$\gamma(T)$	1.00

As the previous example, the impact measured with the eco-gamma is Negligible Impact. This takes sense has river temperature only increases by 0,01 ºC.

3.1.3. WET SEASON

At this season is when the river temperature is the coldest, so here it could affect the big difference there is between river's temperature and the returning water temperature from the company. Even though, this is weakened bay the fact the flow river is the higher.

On that case, river temperature is taken as river's minimum temperature, also optimal temperature takes that value. (Pontigo, 2009)

Table 7: Wet-season eco-gamma data

	Parameter	Value
Global parameters	T_{max}	28 ºC
	T_{min}	7 ºC
	T_{opt}	13.58 ºC
	$T_{affluent}$	7 ºC

Affluent parameters	$W_{affluent}$	304,200 m^3/h
Receiver parameters	$T_{receiver}$	7 ºC
	$W_{receiver}$	303,781 m^3/h

Table 8: Wet season eco-gamma evaluation

Receiver parameters	$T_{receiver}$	7.03 ºC
Global	$\gamma(T)$	1.00

The impact is also Negligible. It is a very little difference of temperature, which does not affect the species living on the river or who lives about the river.

Once the three scenarios are evaluated, it can be determined that GENSA impact on the Nalón River is negligible in terms of temperature.

3.2. **ORINOCO RIVER**

In the Venezolan Amazonas, is located the river basin of Orinco River, the only source of water for the city of Puerto Ayacucho. This area is being submitted to a strong ambient pressure due to the agricultural and urbanistic expansion.

Figure 4: Orinoco River Location

There were three stations where samples were taken, on of them in the first part of the river, in the indigenous community “Gavilan”, the indigenous community of “Las Pavas” representing the middle zone of the river, and finally the lower zone of the river where the local aqueduct is located, near Puerto Ayacucho and where most of the wastewater from the area is located. This samples were taken during 4 different seasons, where water flows vary between the dry and wet season.

3.2.1. AVERAGE ANNUAL

An average between the four seasons are taken is calculated, and the resultant value is considered as the optimal value for the pH during the year.

Values for maximum and minimum are taken considering the flow fluctuations, which make pH variate during some season and these peaks are the one that determinate this parameter. The equation used for the evaluation is the relative to eco-gamma used for the pH (4):

$$\gamma(pH) = \frac{(pH - pH_{max})(pH - pH_{min})}{[(pH_{opt} - pH_{min})(pH - pH_{opt}) - (pH_{opt} - pH_{max})(pH_{min} - pH)]} \quad (4)$$

On this case, if we take for the optimal value the same samples than for the pH, equation gives us a result of 1, which is logical as there is no variation between the optimal value and the value we are evaluating, these means there would be no impact, so wet and dry season are excluded from the calculation of the pH, considering only when water ascends and decline. Parameters found to use on the equation (Table 9) and results (Table 10) are in next tables. (Astiz, 2012)

Parameter	Value
pH_{min}	3.50
pH_{max}	6.20
pH_{opt}	5.356
pH	5.61

Table 9: Orinoco River eco-gamma data

$\gamma(pH)$	0.95

Table 10: Eco-gamma evaluation

The impact during the year, according to the values taken is considered as a Negligible Impact.

3.2.2. DRY SEASON

On this case, there is a particular parameter which is especially striking, the pH. On the first stage of the river, pH is relatively constant during the four seasons, but once river flows, at the dry season, pH decreases in a significative way. This parameter could be studied and analysed by the eco-gamma equation. In table 11 a summary of the input data for the evaluation is found.

Table 11: Dry season eco-gamma data

Parameter	Value
pH_{min}	3.50
pH_{max}	6.20
pH_{opt}	5.356
pH	3.55

The minimum pH during the year is around 5.5, except in the critical dry season, where the flow of the river decreases and the agricultural effect from half of the river downstream is considerably higher. At this point the minimum pH is 3.55, that is the reason why the minimum pH for the evaluation is set at 3.50. Anyway, this pH does not come instantly but is a slow progression produced by the flow decrease and an agricultural activity increase. (Astiz , 2012)

The result of the evaluation is found o the next Table 12.

Table 12: Dry season eco-gamma evaluation

$\gamma(pH)$	0.04

According to the categories set on Table 3, the impact on this case is Extremely High. That means that species life is in danger during this season of the year, it would be interesting to know if there are organisms, like bacteria, that have developed some kind of resistance animals, like fishes, move to another part of the river, upstream, or there is a cycle where a major part of the fauna dies and once the conditions turn habitable comes life again from the upstream.

3.2.3. WET SEASON

During this part of the year, the impact may be the lowest, as a major flow in the river implies that substances, like could be the ones that increase the pH, get dissolved more easily. At this case, the values taken are the ones belonging to the raining season of the year. The values of maximum and minimum pH are the same than in the previous cases, as well as the optimal value. In the following Table 13 parameters are set. (Astiz, 2012)

Table 13: Wet season eco-gamma data

Parameter	Value
pH_{min}	3.50
pH_{max}	6.20
pH_{opt}	5.356
pH	5,83

Once the evaluation is made with the eco-gamma equation, results are shown in the next Table 14.

Table 14: Wet season eco-gamma evaluation

$\gamma(pH)$	0.79

Contrary to what was supposed, the impact during this season is Very High, this is because the low values of pH during the dry season makes the optimal value, the one is taken as a reference decrease, so once the evaluation is calculated, with a 5.18 value of pH, is a very high value for the animal and species habiting in that river, this may be because the hard conditions of a low pH value, make that living beings get used at it, so when pH stabilises in what is considered as a "normal pH", this species are in serious danger.

Definitely, this is a strange case where animals and bacteria, not only the ones that live inside the river, also the ones that drink from it or have some kind of relation with the ecological system formed by the river, have to be prepared for a hard pH conditions. This pH values change a lot between dry and wet season, even arriving to peaks around 3.50, making the water extremely acid when talking about a river.

3.3. **PERUVIAN AMAZON**

Oil demand in increasing globally, and its extraction takes places under ecologically sensitive environments, one of them is clearly the Amazon. In the Peruvian Amazon oil have been extracted for around 40 years, expanding the action territory, and removing it from the indigenous tribes. This activity has polluted the river for years, and specially increasing the levels of metals such as cadmium, lead, chromium, or barium among many others. (Yusta-García et al. 2017)

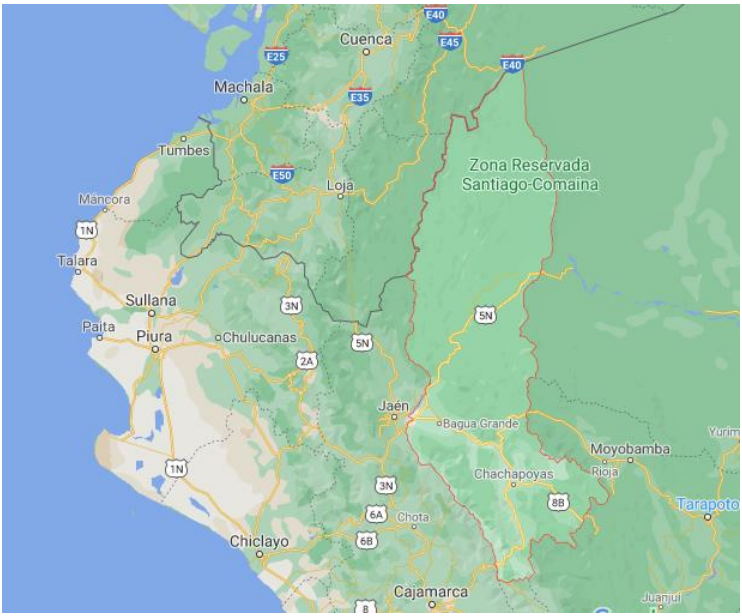

Figure 5: In red, the Peruvian Amazon

3.3.1. Lead concentration

On this case, is going to be studied the impact of lead produced from these activities to the ecological system.

Firstly, as in all the cases, maximum and minimum levels of lead must be determined, and in this case the minimum level will be set in 0, as with no human action there would be no lead, or concentration would be negligible, while the maximum will be in 0,01 mg/L., the maximum legally

permited (Maw et al. 2017). There is no data about the optimal value of lead in river water, so this value is going to be set by taking the average value between minimum and maximum values, at 0,05 mg/L. The remaining value is the Pb concentration desired to evaluate. This value will be settled by taking the average number between all the data recorded, as it is the only way to determine a representative value of all the area (table 15.).

Table 15: Lead concentration

Pb	0.0152 mg/L

Hence, data found for the evaluation through the eco-gamma equation is in Table 16.

Table 16: Eco-gamma data

Parameter	Value (mg/L)
Pb_{min}	0
Pb_{max}	0.01
Pb_{opt}	0.05
Pb	0.0152

The eco-gamma evaluation is made, and the results are presented in the next Table 17.

Table 17: Eco-gamma evaluation (Pb)

$\gamma(Pb)$	-0.06

With this value of Pb, the eco-gamma evaluation turns into a negative value. This is physically impossible in terms of bacteriological growth, as there is no option to be a negative growth. But it takes sense when understating this value as a condition where life for bacteria is impossible, there can be no growth, it is a deadly area.

3.3.2. Chloride concentration

On the other hand, and having also data about the chloride concentrations in the water of the area, this aspect is going to be also evaluated.

As it was done before, it is necessary to set the lower and higher values. Here, the maximum concentration legally stablished is 250 mg/L, and the value established as the minimum concentration will be 0. (Maw et al. 2017)

The optimal value will be taken in between these two parameters, 125 mg/L. In the next Table 18. The parameters used for the eco-gamma evaluation are found.

Table 18: Eco-gamma data (Cl)

Parameter	Value (mg/L)
Cl_{min}	0
Cl_{max}	250
Cl_{opt}	0.05
Cl	437.8

The Cl concentration has been found by taking the average value between all the data recorded.

As in the previous example, the concentration of Cl is much higher than the legally allowed, so this makes already think that the impact must be high. Even though, it is interesting to see the results obtained by the eco-gamma evaluation (Table 19) and set a realistic view about the ecological impact.

Table 19: Eco-gamma evaluation (Cl)

$\gamma(Cl)$	-5.26

The impact on this case, and on the same way as on lead concentration, is a deadly impact. There is no possible life for species living on this habitat as the chlorides concentration is much higher than what life resist.

With all these evaluations made, is correct to secure that the impact that oil industry has done to the ecological system during the last of the Peruvian Amazon it is Extremely High. The impact has only been measured on chloride and lead concentrations, but it is possible than in many other substances and metals the answer may be the same. Amazon is one of the most important ecological systems around the world, and one of the reasons is due to the big amount of water there is, having the water in this shape make species and environment very vulnerable, not only for humans, but for the animals and species that inhabit on it.

3.4. **LLOBREGAT RIVER**

On this case, the mission is to, from a simulation of a circulating cooling water waste heat, evaluate if this systems fits, for example, in the Llobregat River.

Foremost, it is necessary to define what the necessities of this plant are. It is about a thermal power plant, and 16 new cooling towers with a circulating water treatment capacity of 5 m^3/h per unit, which makes a total of 80 m^3/h. The outlet circulating water at 316K (42.85 ºC), flows to the cooling tower, cools down to 305K (31.85 ºC), and then, returns to the plant or in some cases, could be returned to the river. During this process, there is an evaporation factor, which in this case it is a 1.71%, which means, from each 5 m^3/h entering to the cooling tower, about 4.9145 m^3/h came out from it. (Yang et al. 2021)

On this case, as the water is only used on the cooling towers, the unique parameter that it could affect the ecological system is temperature, as water does not take part in the process as a product, does not suffer pH or concentration changes.

In second place, the Rio Llobergat characteristics are defined in Table 20.

Table 20: Llobregat River parameters

Type of parameter	Parameter	Value
Global parameters	Temperature (ºC)	14
	Flow (m3/h)	68,400

With this information is, a mass balance is made to know at which temperature the river ends once the refrigerating water from the plant is retuned. Results are found in Table 21.

Table 21: Mass balance result

$T_{receiver}$	14.02 ºC

As it is appreciable, temperature does not increase a lot, even thought, an eco-gamma evaluation is made to see the impact on the ecological system.

3.4.1. Evaluation

For this evaluation is necessary to define the maximum and minimum temperatures of the river, to define the temperatures that the species that habit on it can resist. It is important also to set an optimal temperature, which will be the most favourable temperature for the ecosystem.

In the next Table 22, are registered all the conditions of the plant and river to evaluate the impact.

Table 22: Eco-gamma data

Type of parameter	Parameter	Value
Global parameters	T_{max}	19.2 ºC
	T_{min}	10.4 ºC
	T_{opt}	14 ºC
Affluent parameters	$T_{affluent}$	14 ºC
	$W_{affluent}$	68,400 m^3/h
Receiver parameters	$T_{receiver}$	14 ºC
	$W_{receiver}$	68,398.8 m^3/h

With all these values settled, eco-gamma evaluation is possible, and the results are found in Table 23.

Table 23: Eco-gamma evaluation

$\gamma(T)$	0.99

Once the eco-gamma evaluation is made, the impact that would produce to the Llobregat River this plant with their circulating cooling towers in Negligible.

This evaluation could have been made in any river, only by having the parameters of flow and temperature of this river could be done. It is interesting to see, just by simulating your own power plant, through the equation see the impact that this would cause in a certain ecological system.

7. CONCLUSIONS

Finally, some conclusions have been extracted after evaluating the obtained results:

Environmental pollution can not keep growing, as this can turn into important disasters in anear future, with this eco-gamma equation, it has been possible, to quantify and evaluate the impact some determinate sectors are producing to the environment. Also, it has been used for other type of situations, not only by evaluating the impact of existing industries or determinate situations but simulating the effect a concrete industry or chemical plant, among many other sectors, would cause in an ecological system.

The method can work with many other parameters than the used in this article, allowing the evaluation arrive to an important level of accuracy.

When talking about the results, there are some areas around the world that are clearly highly impacted by human activities, while there are some others that still maintain a healthy ecosystem. These areas, the Amazon, coincide both in non-developed areas, or at least, not as developed as the environment that surrounds us in Europe.

REFERENCES AND NOTES

1. Arenas, M. All you need is biology: Efecto de los Derrames de Petróleo en el Medio Marino. https://allyouneedisbiology.wordpress.com/2015/04/23/efecto-petroleo-mar/ (Accessed August 30, 2021);
2. Astiz, S. Instituto Mexicano de Tecnología del Agua: Deterioro del recurso agua en el río Cataniapo, Amazonas, Venezuela Tecnología y Ciencias del Agua, vol. III, núm. 3, julio-septiembre, 2012, pp. 5-20
3. Australian Government Initiative. Water quality Australia: Salinity and Water Quality. https://www.waterquality.gov.au/issues/salinity (Accessed August 30, 2021)
4. Coroller, L.; Jeuge, S. Couvert, O. Christeans, S. Ellouze, M. National Library of Medicine, National Center fer Biotechnolgy Information: Extending the gamma concept to non-thermal inactivation: a dynamic model to predict the fate of Salmonella during the dried sausages process. 2014
5. Denchak, M. NRDC Foundation: Water Pollution, Everithing you Need to Know. https://www.nrdc.org/stories/water-pollution-everything-you-need-know#categories (Accesed August 30, 2021)
6. E. A. Ríos- Villamizar, M. T. F. Piedade, J. G. Da Costa, J. M. Adeney, W. J. Junk. WIT Transactions on Ecology and The Environment, Vol 198: Chemistry of different Amazonian water types for river classification: a preliminary review, 2014.
7. Fondriest Environmental, Inc. “Water Temperature”: Fundamentals of Environmental Measurements. https://www.fondriest.com/environmental-measurements/parameters/water-quality/water-temperature/ (Accessed August 30, 2021)
8. Fondriest Environmental, Inc. “pH of Water”. Fundamentals of Environmental Measurements. https://www.fondriest.com/environmental-measurements/parameters/water-quality/ph/ (Accessed August 30, 2021)
9. International Water Association: Water Utility Pathways in a Circular Economy. https://www.iwa-network.org/wp-content/uploads/2016/07/IWA_Circular_Economy_screen-1.pdf (Accessed August 30, 2021)
10. Min, A. Phyu, K. Nanda, M. Khaing, K. Ohnmar, Saw. Kyawt, K. Thura. A, Thu, A. Phyo, Z. Khin, T. Kyaw, T. Department of Medical Research, Myanmar: Approach to Assessment of Heavy Metals Contamination in Drinking Water, Mandalay Region, Myanmar, 2017
11. Ministerio Para la Transición Ecológica y el Reto Demográfico, Gobierno de España. Confederación Hidrográfica del Cantábrico. Chcantábrico: Rio Nalón. https://www.chcantabrico.es/las-cuencas-cantabricas/marco-fisico/hidrologia/rios/nalon (Accessed August 30, 2021)
12. Ministerio Para la Transición Ecológica y el Reto Demográfico, Gobierno de España. Normativa de aplicación en España relacionada con el Mercurio. https://www.miteco.gob.es/es/calidad-y-evaluacion-ambiental/temas/productos-quimicos/mercurio/normativa_mercurio.aspx (Accessed August 30, 2021)

13. Munné A. Generalitat de Catalunya, Departament de Territori i Sostenibilitat. Agencia Catalana de l'Aigua: Modelización de la calidad del agua en el río Llobregat, 2013.
14. Pontigo, F. Coordinadora Ecoloxista d'Asturies: Aprovechamiento de agua del río Nalón en Trubia para la central de ciclo combinado, 2009. http://coordinadoraecoloxista.org/aprovechamiento-de-agua-del-rio-nalon-en-trubia-para-la-central-de-ciclo-combinado (Accessed August 30, 2021)
15. Plana, J. Una aportación al estudio hidrlógico del Llobregat.
16. Quezada, M. Bonet, J. Plesu, A. Introducing Eco-gamma: A novel environmental impact index for water quantity and quality evaluation. Master of Environmental Engineering, Universitat de Barcelona, 2020.
17. Torey, S. Nuestra Esfera, Espacio Educativo: Contaminación del agua por actividades industriales. http://nuestraesfera.cl/zoom/contaminacion-del-agua-por-actividades-industriales/ (Accessed August 30, 2021)
18. Vancouver Water Resources Education Center: Water Quality: Temperature, pH and Dissolved Oxygen. https://www.cityofvancouver.us/sites/default/files/fileattachments/public_works/page/18517/water_quality_tempph_do.pdf (Acessed August 30, 2021)
19. Walsh, Cepsa Perú. Hidrologia. http://www.minem.gob.pe/minem/archivos/4_1_5%20Hidrolog%C3%83%C2%ADa.pdf (Accessed August 30, 2021)
20. Water Pollution Foundation. Causes of Water Pollution https://www.water-pollution.org.uk/ (Accessed August 30, 2021)
21. WWF Foundation. Water Pollution, 2020. https://wwf.panda.org/discover/knowledge_hub/teacher_resources/webfieldtrips/water_pollution/ (Accessed August 30, 2021).
22. Yang, L. Wang, Y. Hang, Z. Luo, Y. simulation and Economic Research of Circulating CoolingWaterWaste Heat and Water Resource Recovery System. Energies 2021, 14, 2496. https://doi.org/
23. Yusta, R. Orta-Martínez, M. Mayor, P, González-Crespo, C. Rosell-Melé, A. Environmental Pollution 225 (2017) 370-380: Water contamination from oil extraction activities in Norhern Peruvian Amazonian rivers.
24. Zebo, F. Bin, S Dong-Dong, X. Liao-Yuan, Y. Study on pH value and its variation characteristics of the main rivers into Dianchi lake under the anthtropgenic and natural processes, Yunnan, China, 2017.

ACRONYMS

CE	Circular Economy
Cl	Chloride
DO	Dissolved Oxygen
GENSA	Gestión Energética S.A
Pb	Lead
T	Temperature
W	Flow

APPENDICES

APPENDIX 1: TABLES

-NALÓN RIVER

Average Season Nalon River	
Tmin	7
Tmax	28
Topt	13,8
T	13,62
-95,1956	Eco-gamma Value
-95,228	0,999659764

Dry Season Nalon River	
Tmin	7
Tmax	28
Topt	28
T	28,01
0,2101	Eco-gamma Value
0,21	1,00047619

Wet Season Nalon River	
Tmin	7
Tmax	28
Topt	7
T	7,03
-0,6291	Eco-gamma Value
-0,63	0,998571429

-ORINOCO RIVER

Average Season Orinoco River	
pHmin	3,5
pHmax	6,2
pHopt	5,356
pH	5,61
-1,2449	Eco-gamma Value
-1,309416	0,95072918

Dry Season Orinoco River	
pHmin	3,5
pHmax	6,2
pHopt	5,356
pH	3,55
-0,1325	Eco-gamma Value
-3,394136	0,039037917

Dry Season Orinoco River	
pHmin	3,5
pHmax	6,2
pHopt	5,356
pH	5,83
-0,8621	Eco-gamma Value
-1,086776	0,793263745

-PERUVIAN AMAZON

Lead Concentration	
Pbmin	0,0001
Pbmax	0,01
pbopt	0,05
Pb	0,0152
0,00007852	Eco-gamma Value
-0,00113252	-0,069332109

Chloride Concentration	
Clmin	0
Clmax	250
Clopt	125
Pb	437,8
82218,84	Eco-gamma Value
-15625	-5,26200576

-LLOBREGAT RIVER

Llobregat River	
Tmin	10,4
Tmax	19,2
Topt	14
T	14,02
-18,7516	Eco-gamma Value
-18,752	0,999978669