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Effect of Mining by RUSAL Company on Renewable Natural Resources in the Prefecture of Fria, Republic of Guinea

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Abstract The objective of this study was to focus on the impacts of RUSAL / FRIGUIA company's activities on renewable natural resources and to give the situation of the restoration of exploited areas. The study was conducted in the prefecture of Fria / Republic of Guinea from January 1st to June 30, 2012. Three locations were selected for the observations of the exploitation areas. The diagnosis of different activities on the aid of MARP. Analysis and processing of the collected data from processing of bauxite into alumina with regards to increase the pollutants emitted and can no longer be directly assimilated by the environment; installations of the Groundwater; Surface water and air were exposed to pollution; the process of restructuring by setting up methods to minimize the effects of chemicals and the effective restoration of old quarries. Thus the most efficient approach to eradicating the degradation of renewable natural resources by developing a notation for maintaining the level of production while ensuring minimal discharge of pollutants; the implementation of those processes lead to minimize the level of pollution and decontamination.

Keywords: *flora, fauna, pollutant, environment, Fria*

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1. Introduction

At present, we live in a time of rapid changes in the world population and technological innovations. The protection of the environment and management of the biological diversity is one of the major concerns of the researchers, donors and governments in a world where human activities generate enormous quantities of pollutants per day, much of which is directly released into the wild. The manner in which the process of environmental degradation is conceptualized and their original explanations have obvious critical implication on nature and of policy recommendation which will be put forward. According to study in on the Brazilian industry, the main environmental problems associated with bauxite mining are related to the rehabilitation of mined-out areas and the disposal of tailing. Emissions of dust consisting of clay and bauxite particles from dryers' chimneys can also pose problems. In alumina production, the disposal of bauxite residue saturated with caustic soda is the main problem, although the emissions to the atmosphere of gases and particles from boilers, calculations and bauxite dryers can also be important. As we observed, the emission from the production of bauxite and alumina affect soils, air, flora, fauna, and water.

The problem of the environment is more severe in terms of the balance between the natural resources (land, water quality, woody vegetation) on the one hand and, on the other hand, the needs of the rapidly growing populations in the search for a general improvement of living conditions. The natural resources are the set of natural elements (water, vegetation, soil, flora, fauna, etc.) of which humans take advantage of their survival and development [1]. There are various mineral resources, biological necessary for human life and, therefore, in the whole range of economic activities in the industrial civilization [2]. These resources are all tangible and intangible assets which are breed develop without human intervention, put at the disposal of people meet its needs [3]. Renewable Natural Resources can be used without exhaustion as they constantly renew, and they can be identified as such: water, soil (arable land) and so-called biological resources as constituted by the living communities exploited by human (forest, pasture, sea fishery), biodiversity (animals and plants) in which agronomists include what they call genetic resources that are to say all the varieties of crops and breeds of domestic

animals [2], in this study, they mentioned that these resources cannot be considered inexhaustible insofar as the tax rate is lower than the available productivity. Nonrenewable natural resources are composed of the mineral raw materials: metal, metalloid, various uses of minerals, fossil fuels, uranium 235. These resources come from deposits that were formed during the geological era of the earth and correspond to a finite stock of gasoline;

It is the same as natural spaces because the surface of the various types of ecosystems is consequently that of the entire biosphere [2]. Forest degradation has been the main cause of climate change of primary groups, which then gave way to associations or degradation, this was the basis of an imbalance between plant communities, soil humus types, which is more or less stable; in many cases, the destruction of vegetation, soil loss in the major components (chemical) that may be involved in the fertilization and the other in the erosion exposing [4].

Guinea being a "geological scandal" where all metals exist, is not given by protection of these resources. Bauxite is a source of foreign exchange since the 60s; where two-thirds of the productive activities of the country come from the mining sector. Bauxite and alumina production have been of a critical importance to the post-independence Guinean economy. In fact, activities had already begun at several sites during the colonial period and, as is often overlooked, Pechiney's important activities were to continue even after that period. Mining at the prefecture of Fria was initiated in 1957 by the French Pechiney Factory. Production of alumina at this site began in 1960 and reached 460.000 tons in 1962 representing 58 percent of the total value of Guinean exports. The exploitation of bauxite resources of Fria, beyond its economic impact, causes serious harm to the environment as follows: the destruction of vegetation cover, loss of wildlife, river pollution, and atmosphere by the use of chemicals (caustic soda, fuel oil, acid). Environmental concern mining areas are primarily related to mechanical damage of the landscape and acid mine drainage [5,6].

Caustic soda is a highly toxic solution that may affect near and/or indirectly to any form of surrounding life (animals, plants, and microorganisms) even in biotope (rivers, groundwater). It increases the pH of streams representing a potential threat to flora and fauna. All these conversion processes result in a depletion of the flora, fauna, and ecology. Faced with these realities, the environment in general and natural resources, in particular, deserve at all costs to be preserved not only by environmentalists but also by polluters who are primarily mining companies. To minimize these impacts, the mining companies emit mitigation and compensation measures; develop rehabilitation plans as part of the natural resource management plan. These measures are not fully respected in their terms of engagement because RUSAL is mainly involved in the rehabilitation of quarries that promotes soil restoration. In our study, it is emphasized that no restoration plan is envisaged for other renewable natural resources. Now if these degradations are not followed to protect (or adapted to agricultural practices) large-scale loss of forest cover leads to a rapid flow of water, soil erosion, siltation, and flooding in during the rainy season, a decrease in river flow in the dry season and a push disappearance of wildlife. In extreme cases, this can lead to the complete drying of the river in the dry season with all that it entails disadvantages for natural resources.

It sometimes seems inevitable that human and natural factors can cause landscape changes. However, knowledge of land use and land cover can be important in the national plan if used to reverse deteriorating environmental quality trends, loss of wetland, wildlife habitat and ecological pollution [7]. In order to assess the contribution of RUSAL in its environmental monitoring program for the site, in accordance with regulatory requirements and recommendations of the evaluation about the appropriate role of the mining sector in the management of renewable natural resources in the settlement area, we have proposed to conduct this study. Our point of entry to these broad interrelated questions as they relate to Fria's environmental policies in the mining sector will be the role of the RUSAL and more specifically, to study the alternative conceptualizations and its role in the environmental policy process as revealed through the analysis of different planning documents.

2. Materials and Methods

2.1. Study Area

Fria is one of the thirty-three prefectures of the Republic of Guinea Conakry and the five prefectures account the administrative region of Boke. It is located in the contact area of maritime Guinea and the Fouta Djallon 160 km from the capital Conakry [8]. It covers an area of 1811 km^2; its population is estimated to 98,408 inhabitants, with a density of 54 inhabitants/km^2. It is between 10° 25' and 10° 47' north latitude, 13° 25' and 13° 34' west longitude at an average altitude of 210 m. It has three rural communes (CR) and the urban commune. It is bordered in the north and north-east by the prefecture of Telemele, in the south and southeast by the prefecture of Dubreka, in the west by the prefecture of Boffa.

The climate of that prefecture is characterized by the alternation of two seasons: a dry season from December to May and a rainy season from June to November. The rainiest months are July and August with a rainfall height from 1800 to 4100mm depending on the season. There are two prevailing winds: the monsoon blowing from the sea to the mainland (the low pressure to the high pressure) and the Harmattan which blows from the mainland towards the sea. The relief of the prefecture is characterized by plateaus punctuated by hills. In this area, soil type includes Skeletal, ferrous and temporary hydromorphic in most cases. The hydrography of this area is well served with water, with many rivers and their source from Kounkoure River and Fatala River to the Atlantic Ocean. All these rivers have temporary regimes caused by the destruction of watersheds by the activities of the RUSAL Company.

Vegetation is characterized by the presence of different types of savannas that have been settled after the destruction of the original primary forest. The population in the districts within the urban commune, practices pomology and private nurseries. To the heights, we meet some forest patches that tend to disappear as a result of bushfires, the slash and burn, the coal mine and especially of bauxite mining activities. The pushing vegetation

degradation caused by the activities of the RUSAL Company has led to the disappearance of certain animals, some species have become rare. On the contrary, duikers (Cephalous sp.) are still abundant in the coastal districts of the factory. It is important to note that the main socio-economic activities of the population of this prefecture are: Agriculture, the Peach, the hunt, the livestock, the trade, the handicrafts and the Colliery.

Figure 1.

2.1. Overview of the History of the Factory of the Fria

The Factory of the Fria is located at 5 km from the center on a slight slope hill; its purpose is the extraction and processing of bauxite into alumina through the Bayer process (Swedish scientist) according to different sides:

- **Sector or red side:** consists of crushing, grinding, attack, a hydro separator (grit), desilication, causticizing, deoxalation, decantation, filtration and red evaporation.
- **Sector or white side:** composed exchanger, white filtration, and decomposers;
- **Sector or Calcined side:** consisting of upstream of 100 °C to remove moisture water and downstream of 1000 °C to remove structure water.

The sum of these four gutters is the channel that drains into featuring which in turn empties Konkouré River. Those pollutants entering the transformation of the alumina bauxite are sodium hydroxide, hydrochloric acid, lime, and oil. The factory of the Fria is the first alumina refinery in Republic of Guinea Conakry and has started the implementation work in March 1957. It has been inaugurated April 30, 1960, under the name Fria Company and on February 18, 1973, it becomes FRIGUIA mixed economy Company with the Guinean State holds 49% interest rate and 51% by foreign shareholders. The theoretical production in 1960 was 480 000 tons/year of calcined alumina. The record production was realized in 1980 with 691,840 tons of calcined alumina. The nominal alumina export capacity is 640,000 tons of alumina/year.

Since its takeover by ACG (Alumina Company of Guinea) in March 2000, there has been a marked improvement in production, engineering and at the level of mining and the reliability of the facilities themselves. The current average production is 670,000 tons/year and

the company is already planning the future production of around one million tons. On March 1, 2000, Reynolds metal actually, operates services on the site and careful manner. Since December 2002, Russki Alumina (RUSAL) has become the main investor of the Company. On January 1, 2007, the Company changed its former name into RUSAL / FRIGUIA. In the factory, there is an environment department under the supervision of the Industrial Security Directorate and the environment and headed by a Chief of Department. He has a foreman, a responsible sludge and a laboratory built in 2007 to determine the pH of the effluents in the various gutters of wastewater disposal and to determine the salinity and pH of rivers in the area surrounding the factory.

2.2. Methods

To assess the contribution of the RUSAL Company in the management of renewable natural resources, the following methodology has been used:

2.2.1. Literature Review

This phase consisted of the compilation and exploitation of the bibliographic resources including the study or consultation reports, the physical aspects of reporting, biological and socio-economic characteristics of the medium, the activity reports of technical services, scientific papers and articles published in this area.

2.2.2. Interviews and Participatory Data Collection

These surveys were conducted on the basis of Participatory Rapid Method (PRM) by using sheets of investigations established for this purpose and addressed to the different services and the local population.

2.2.3. Field Investigation

In order to verify the veracity of the information received from the respondents, we conducted a field visit to finger all realities. The intervention area was completely covered in order to conduct observations there and to highlight measures of tangible impacts of plant operations in the environmental field.

2.2.4. Analysis and Processing of Data

At this point, we proceeded to group the data and then we have classified them according to criteria to offer solutions for improvement.

- **Sampling method**

First method

It was consisted of taking a sample of each gutter from the factory in a bottle bearing the numbers gutters;

Second method

It was consisted of taking samples from six ordinary wells, drilling and surrounding Rivers in bottles bearing indications of sampling locations.

- **Method of analysis samples**

Water Testing gutters and water wells, boreholes and rivers were made in two types of analysis

The cold analysis

This analysis concerned of samples taken during the four gutters and the channel at the factory, three times a day and at different times (8 am, 11 am and 3 pm). It consisted of taking 50 mL of the sample, introduce them into a beaker and set two drops of phenol with the presence of caustic soda which is the indicator, the solution turns pink, and by titration with hydrochloric acid concentration of N/2 equivalents to 15.5 g/L until the disappearance of the color, and to note the volume of the poured acid. Then after that we determined the concentration of the caustic soda present in the sample which passed through the NA = NB equivalence relation where CA x VA = CB x VB.

$$C_{HCl} x\ V_{HCl} = C_{NaOH} x\ V_{sample};$$

where $C_{NaOH} = (CHCl \times V_{HCl})/V_{sample}$.

Hot Analysis

This analysis concerns waters ordinary wells and boreholes, streams and effluents from the factory. The analysis of these sources of water in the different districts was about identifying with accuracy and precision the situation faced by local residents and others. It was done by sampling 50 ml of sample to be introduced into an Erlenmeyer being taken on a hot plate and then put two drops of phenol. With the temperature rise, the sample turns pink, indicating the presence of sodium hydroxide and titration using a burette from 0 to 25 mL containing hydrochloric acid concentration of N/2 then drained until the disappearance of the hue, then measuring the volume of the acid poured in order to assess the concentration of caustic soda in the sample by the expression:

$$C_{NaOH} = (C_{HCl} x C_{HCl}) / V_{sample}.$$

The second analysis was consisted to determine pH of the different samples by using a pH meter. The result is displayed in the following intervals:

- From 0 to 6.99; the sample contains acid;
- From 7.01 to 14; the sample contains soda;
- And at 7.00; the sample is neutral.

For the determination of the area of exploited quarries and restored we had only the information provided by the topography and environmental services. Both services were responsible for assessing the area harvested and the restored every year. These successive analyses of biophysical data allowed us to identify the factors affecting degradation of different natural resources, socio-economic and environmental impacts. The research took place from January 1st to May 30, 2012, inclusively in the prefecture of Fria.

3. Results

3.1. Diagnosis of the RUSAL Company's Activities

During this operation, we have first the alienage which is an open-access technique by using bulldozers. Then, the company carries out the clearing and stripping operations that are done in one operation which always uses bulldozers. Add to this, it involves blasting to demolish rocks, load and transport the ore to the level of crushing. The alumina refining uses the process developed by "Karl Bayer" in the 60s, process that consists in selective solubilization of the alumina with sodium liquor (NaOH)

high temperature and pressure followed by separation of the sodium alumina solution. This transformation is split into three areas or sides:

Red Sector: This phase concerns the various purely chemical steps;

White sector: In this sector, alumina which has been melted in the attack with the soda liquor will return to the state of small grained.

Calcined sector: The alumina grains from the white filter are made of pure water and alumina. To obtain a good quality of aluminum, the alumina should be pure without water. It is in this sector where pure alumina is made by removing water of each grain. This sector includes workshops upstream and downstream calcination.

3.2. Detailed Assessment of Impacts Resulting from These Activities

The mining policy should address two concerns: that of the development of natural resources for the promotion of a coherent socio-economic development on the one hand, and especially, a balanced reconciliation of mining to the preservation and protection of the environment. Environmental damage caused in the industries, in general, is inherent in the production process used. In appearance, the bauxite industry in Guinea and those of alumina refining met only Fria are no exception to this rule. In doing so, the identification of environmental damage caused in this society requires, above all, to go at the origin, from the place where resources are produced following step by step what is the environment to exploit it. To better highlight these impacts, we preferred to take account of renewable natural resources separately.

3.2.1. Forest Resources

Fria, because of the actions of human in general which result in significant changes in the vegetation, the extraction process of bauxite used by the company led to the destruction of vegetation contributing to the reduction of forest areas and the disappearance of valuable species. In this prefecture, part of the most of part of the forest was replaced by Savannah with palm trees that occupy the plains. Mangrove areas were converted into the rice-growing area. Savannah is slightly raised with scattered small. On the basis of a predetermined list in collaboration with the Water and Forestry Section, our observation has shown that some species are no longer found in the area of exploitation. It is noteworthy that during our research one classified forest of 25 hectares located in the neighborhood of Tabossy district was identified. It appears from this table that among the thirty-three species identified, 11 are abundant, 15 are rare in the area of operation and 7 have disappeared (data not shown). The cause is that after the operation careers are reforested from exotic species that do not promote the maintenance of local species in that area.

3.2.2. Wildlife Resource

3.2.2.1. Terrestrial Fauna

The forests in the urban commune of Fria are not full rich, probably because of bush fires, shifting agriculture and especially mining has severely affected wildlife, particularly large mammals. Besides this, the commercial hunting is encouraged by the strong demand for meat, and for the population's food. Big animals are far from the intervention areas of the company, in the sub-prefectures. Reptiles such as snakes and green lizards are found in the area. The main birds of the area of operation are crows, pigeons Guinea, vultures, parrots, woodpeckers, partridges and guinea fowl; this is made possible by a pre-established list from the Division of Forestry of Fria. Table 2 shows the current status of the wildlife of the area of operation. The data in that table show that all large wild animals that existed until 1998 are scarce in the area of operation in 2012. This is explained by the strong anthropic pressure in general and mining in particular through the blasting and transport singularly.

Table 1. Terrestrial fauna in the area of exploitation

N°	Scientific noun	family	current situation		
			1998	2002	2012
1	*Cephalophus sylvicultor* (A. Liu)	Bovidae	+	+	+
2	*Cephalophus flatus* (Gray)	Bovidae	+	—	—
3	*Cercopithecus aethiops* (Gray)	Cercopithecidae	+	+	+
4	*Erythrocebus patas* (Schreber)	Cercopithecidae	+	+	—
5	*Pan troglodytes verus* (Blumenbach)	Pongidae	+	—	—
6	*Cyncerus caffer* (Sparrman)	Bovidae	+	—	—
7	*Triomomis gambianus* (Thomas)	Triomomidae	+	+	—
8	*Heliosciurus gambianus* (L)	Sciuridae	+	—	—
9	*Papio cynocephalus papio* (L)	Cercopithecidae	+	—	—
10	*Potamochoerus porcus* (L)	Suidae	+	—	—
11	*Hystrix cristata* (L)	Hystriscidae	+	—	—
12	*Pedestes capensis* (Forster)	Leporidae	+	—	—
13	*Phacochoerus aethiopicus* (Dallus)	Suidae	+	—	—
14	*Canis vulpes* (L)	Canidae	+	—	—
15	*Canis adustus* (Sundeval)	Canidae	+	—	—
16	*Felis silvestris* (Schreber)	Felidae	+	—	—
17	*Cricetomus gambianus* (Waterhouse)	Cricetidae	+	+	—
18	*Testudo sp*	Chelonidae	+	—	—

Legend: + (Present); — (Disappeared).

3.2.2.2. Aquatic Fauna

Most aquatic wildlife resources come from two rivers that flow in the Prefecture of Fria: Konkouré and Fatala. Reptiles like crocodiles are found in swampy areas and waterways. According to our investigations, no crocodile was seen in the Konkouré River near prefecture of Fria because of the speed of the current. It is important to note that in 2003 and in the two rivers more than 37 fish species were recorded. Actually, these rivers are facing the problems of pollution due to spillage of caustic soda, acid and red mud in the scarcity of some species and the disappearance of others. Our investigation shows that compared to 2003, in 2012, the disappearance of many species due to spillage of liquid effluents (soda, acid, hydrocarbon, oil ...) have been observed and red mud that causes pH change and thus the changes in the marine ecosystem (data not shown).

3.2.2.3. Disruption of the Breeding System

This exploitation has a negative impact on livestock, throughout the process of mining and blasting, during which, large blocks were projected fall on the animals in search of grass. Those animals (cattle, goats, and sheep) are influenced by the external environment and can be affected not only by absorbing pollutants by breathing but also by the ingestion of plants on which pollutants were deposited or have been stored. It is known that air pollution disrupts the regenerative action differently while changing the composition of the life support systems of the plant (light, air, water, and soil).

3.2.3. Water Resources

During the stripping and clearing work, topsoil that is pushed by bulldozers just plugs the nearby waterways. During blasting, the block portions that fly to these waterways not only pollute but also kill aquatic species existing there. Moreover, this is the spill of caustic soda and other chemicals in rivers and generally, the groundwater does not escape from this situation.

3.2.3.1. Surface Water

After monitoring and analyzing the pH of the alumina soda that was conducted as part of the realization of our research on several sites and river Konkouré River which is the most important rivers of Fria and situated at 2 km the factory site, the results have indicated that pH values are higher than the limit values at the confluence between river Dote, Konkouré River and Lake River which is to be linked with the current practice of throwing into the aquatic environment caustic effluent from the storage of red mud. The results of Table 2 show that all the waters of the Lake River are rich in soda which causes pollution by infiltration of groundwater and runoff. We have noted that all pH were high and it represents a hazard to aquatic life (Table 3). According to the World Bank, it is recognized that the allowable tolerance for mining companies in terms of pH is 9. The observations in Table 4 indicate that the effluent concentration at some levels in caustic soda is not conforming to the tolerance shown by the environmental department of the factory; this is due to leakage in the facility, piping and overflow scrubbers settling.

Table 2. Result of water analysis of Lake River

place	pH		Total of soda (g/L)	
	founded	tolerance	founded	tolerance
Source of River	10,66	9	1,55	0
Middle of River	8,40	9	0,69	0
Purification	9,70	9	0,79	0

Table 3. Result of water analysis to the dam of mud and Konkouré River

	pH		Total soda (g/L)	
	founded	tolerance	founded	tolerance
Upstream of the dam	11,20	12	1,96	3
Downstream of the dam	11,16	12	1,95	3
Infiltration	10,64	12	1,19	3
Coming from to River	11,80	12	1,80	3
Junction	11,60	12	0,50	2
100 meter from junction	10,50	11	0,41	1
500 from right bank of River	7,76	10	0,10	0
500 meter from middle of River	7,05	9	0,02	0
500 meter from left bank of River	7,15	9	0,10	0
Water of Konkoure River	7,38	12	0,06	0
Average	9,66	–	1,16	–

Table 4. NaOH content of the water effluent from the factory after analysis

times / Gutter	8h	11h	15h	average	tolerance
1	0,16	0,16	0,14	0,15	4
2	1,32	1,66	2,09	1,69	4
3	4,96	1,46	14,26	6,89	4
4	0,31	0,12	0,05	0,16	4
Channel	1,69	1,09	4,14	2,30	4

Table 5. Piezometric water analysis from the factory, wells of the different district (Tigue, Aviation, and Tabossy)

designation		pH		Total soda (g/L)		Depth of wells
		founded	tolerance	founded	tolerance	
Piezometer in the factory	Heavy equipment	6,13	9	0,00	0	20
	Crushing	5,39	9	0,00	0	27
ordinary wells	Tigue district	7,19	9	0,062	0	15
	Tabossy district	4,66	9	0,00	0	12
	Aviation district	4,83	9	0,00	0	17
Drilling wells	Tigue district	7,15	9	0,061	0	60
	Tabossy district	7,05	9	0,031	0	55
	Aviation district	6,69	9	0,00	0	65

3.2.3.2. Groundwater

After analysis of groundwater in terms of quality parameters including pH and soda on six wells in nearby villages at the factory, the results showed that in the upstream refinery (village Tabossy), the quality of ground water in the surficial aquifer is generally conformed to OMS standards for drinking water. Non-conforming values were nevertheless recorded (suspended matter, alumina) in downstream of the refinery (Tigue district and aviation district). The quality of the deep aquifer is up to standard; we may note from the analysis of this table, that well of Tigue district contained a certain amount of soda, this was explained by the fact that this district is located in downstream of the factory down a hill and the other sites are located upstream of the processing factory (Table 5).

3.2.4. Soil Resource

The work of stripping and cleaning was always done by using bulldozers that cause the complete destruction of vegetation. These facts were reported but also checked at the careers of the industrial unit prefecture of Fria where the degradation of the landscape is observed. Everywhere, this work has led to a modification of the landscape (aesthetic damage), threaten and cause physical damage to the soil after water erosion. The major risk incurred is that of chemical degradation following the blast which can lead to loss of productivity of agriculture and grazing. It is important to remember that a part of the cropped area was used as a sand dump, red mud and sedimentation crust which also increases pollution levels due to fly-off of the waste.

3.2.5. Air Pollution

The sources of contamination or dust that could affect the quality of the air are the following:

3.2.5.1. Aerial Factory Emissions

They are rejected with two fireplaces 60 m (power plant) and two other chimneys 60 m and 50 m (calcination unit);

3.2.5.2. Dust Emissions

Dust generated by specific activities in the factory (alumina loading, unloading and storing the lime) and vehicles used for transporting bauxite quarry to the plant remain localized in the areas of activity and their immediate surroundings. The first source is the quarry where the explosives of trucks loaded with ore on tracks 12-20 m wide cause uprisings in dry periods; the second source is related to the processing of bauxite (crushing and drying). During the crushing especially in the dry season, the winds carry dust as fireplaces that release into the atmosphere where they can have very harmful effects for the proper development of renewable natural resources in their entirety. So we have made a summary of impacts and mitigation measures are recorded in Table 6 Analysis of this table leads us to show that the environmental damage resulting from this operation is quite numerous, and result in the destruction of soils, the accumulation of material released into the environment, contamination of waterways and air pollution. This was explained by the fact that they directly affect the main receiving environments such as ecological and socio-economic background.

Table 6. Impacts of different activities from factory, levels and compensation measures

Source	Impact / appearance	Levels	Mitigation
quarry	Absence of collection of runoff from careers	moderate	Build ditches and/or gutters along the tracks leading to careers in order to collect runoff
	Noise and vibration associated with firing of explosives	moderate	Identify areas where blasting could cause damage or nuisance to local communities
	Mishandling of explosives	Very significant	Manage explosives in accordance with international best practices
	Inadequate rehabilitation of old quarries	moderate	Run the old quarry rehabilitation program
Factory	Emission of SO_2 and dust	moderate	Renew filters calcination furnaces; Run the air emissions management program
	Uncontrolled release human waste	Very significant	Create a separate collection system sanitary water; Retrieve and create a wastewater treatment plant
	Uncontrolled release of storm water	Very significant	Centralize discharges from the factory and clearly separate those from red mud, recycle and neutralize effluents;
	Uncontrolled release of washing water	moderate	Establish monitoring systems at the plant to contain soda, liquor, red mud, and hydrocarbons;
	Rejection of red sludge liquors	significant	Divert storm water to minimize water entered the plant sanitation circuits
	Contaminated groundwater to the right side of the site	significant	Establish a monitoring program of the quality of surface and ground water that can be used in needs
	Poor equipment and consequential risk of leakage of steam	significant	Gradually modernize the plant by targeting priority areas as critical attack and desilication

3.3. Result of Socio-economic Surveys

3.3.1. Results of Surveys in Villages

Following various meetings with representatives of the villages concerned with members of the joint committee responsible for the prevention and management of environmental impacts, we went to the field to verify the statements made by the spokesmen of the communities concerned. After field visits, we have harmonized the views on the facts findings and solutions to promote good cohabitation between riparian careers and RUSAL Company. The results of these findings showed that in general that the riverine communities face the same kinds of problems that are usually due to the effects of blasting among which include: Reduced growing areas, Lack of drinking water, cracking buildings, emission dust during blasting; pollution and siltation of villages for example (Baguinet rivers, Boundoubaga, and Tèrègbèsset), encroachment plantations with red mud; there is also an insecurity in some coastal villages because of the proximity of particular careers Kaléma, Fokibo, Kondékhouré et Boundoubaga.

3.3.2. General Problems

Beyond the study of particular cases of the effects of quarrying operations on neighboring communities, we were interested in environmental problems in their generality. Despite made by the company RUSAL/FRIGUIA for the protection of the environment through the implementation of several projects which are among others: construction of dams 1, 2, and 3 of Dote, construction of wastewater collection channel, reforestation of quarries, safety measures at the plant and the railroad, many environmental and social problems remain on hold such as:

- Deficit of communication between the company RUSAL/Friguia, the prefecture and local authorities, pollution of groundwater and river water infiltration soda and dumping wastewater composed of oil, hydrate, caustic soda;
- Mismanagement of the red mud and sand sodium;
- Atmospheric Pollution: dust, smoke, alumina and other soaring gas;
- Presence of toxic waste and contaminated land;
- Destruction of aquatic fauna, disappearance, and remoteness of the wildlife;
- Silting and disappearance of rivers;
- Reduction of arable areas;
- Improved method reforestation.

The analysis of these items lets us see that all the coastal villages have ideas that converge on the same points: the improvement of their living conditions through:

- Support for income-generating projects and the creation of jobs for the local population;
- Participation in local government development actions;
- Respect of the code of the environment and the charter companies in force in the Republic of Guinea, which requires that the environmental protection is on the top of priorities.

3.3.3. Results from Surveys Prefectural Authorities

Our investigations have noted that during the refining of alumina, the raw materials used therein causes very harmful effects that could be summarized by pollution. This pollution is usually caused by wastewater through gutters grouped in the channel. According to those surveyed, we find four types of pollution:

Pollution from Liquid Waste

A suspension to the liquid effluent channel and the channel silted overflowed to Tigue Valley, which resulted in the presence of an amount of sodium hydroxide in the LAKO River and upstream watercourse of the Sabendè district until Tigue district. 19 persons burned by soda and sheep have been observed for three weeks; the presence of that sodium hydroxide was observed in the bed of the Sabendè River located 2 kilometers from Tigue district to Touba district and fish that existed there were all dead by the hydrate. This pollution cause's degradation of the landscape through the discharge of highly toxic waste through the gutters always directed to the surrounding neighborhoods, which later affects the water table;

Pollution from solid waste

These wastes are usually red mud, sand, lime and alumina from manufacturing workshops alumina. According to information from the environment department of the factory, each tone of sludge contains an average of 15 kg of unrecovered sodium hydroxide. This mud under the effect of the sun is changing and is transmitted to living organisms because the fly-off and subsequent respiratory diseases and rivers are polluted.

Pollution by gases

Gas (nitrogen monoxide, carbon, and sulfur) from all of the power plant and the calcined cause serious pollution and disrupts the atmospheric air. These gases once accumulated in the atmosphere, gradually destroy the ozone layer.

Pollution loading and transport of alumina

These operations cause very important damage. During the delivery of the calcined alumina from the furnaces to the alumina storage silo including the crossing on the conveyor belt, there is a fly-off of an uncontrollable amount of alumina as dust at the time of loading in wagons.

3.4. Assessment of the Status of Renewable Natural Resources and Possible Threats

According to the results obtained on the main activities of the Company RUSAL, it seems essential to make a priori assessment that meets an environmental policy, which corresponds to the implementation of the fundamental principle of prevention, but also and above all assessment reflects the integration of environmental policy, for a sustainable development. The importance of this assessment is to raise the problem faced by the media (physical and human). In the specific case of this study, we used as an evaluation tool the matrix of LEOPOLD et all. [9] which is the best known among the evaluation matrices method. This matrix offers both the possibility of identifying and assessing impacts (Table 7). Analysis of data in this table showed that all the activities developed

by the RUSAL have impacts on different elements of the environment on the different levels. The cause maybe the different ways used by different sector. Among all the elements of the environment, water resources are the most affected due to the frequent use of chemicals that are usually drained to these environments.

3.5. Situation of Restorations Made by RUSAL

The future use of the soil must be fixed prior to the selection of species during the public consultation process with the authorities, surrounding communities and potential owners of rehabilitated quarries, and this is not currently the case with RUSAL where neither the local population nor the technicians of the Prefecture are involved in the rehabilitation process. If careers will be used for agriculture purposes, the selected species should be those cultivated or grazing in comparable areas. Species selection should also aim to improve the soil.

It is important to plant legumes such underbrush, as they increase the ability of soil nitrogen that further improves its fertility. This is relevant for the Fria region that is characterized by lateritic soils which are naturally infertile. Experience advises the continued use of planting *Acacia mangium* and *Acacia auriculiformus*. However, it is imperative to introduce a wider range of species to increase biodiversity in rehabilitated quarries. During our research, we were able to make the situation of exploited quarries and those rehabilitated under the direction of RUSAL between 2002-2011 (Table 8). It appears from the analysis of this table that restored surfaces were superior to those exploited. This was due to the fact that RUSAL also comes as part of the restoration at the old quarries exploited by first partners. We also noted that the planted species remain almost the same in all careers, hence the need to reforest these areas with species that existed before the operation to talk about the actual restoration.

Table 7. Matrix Impact shares in the RUSAL Company on the environmental elements

	Activities / Environmental element	Scouring	Blasting	Transport	Grinding	Attack	Desanding	Dilution	Desiccation	Decantation	Washing	Red filtration	Exchange	White filtration	Evaporation	Calcination
BIOPHYSICAL	Underground water		■			■					■			■	■	
	Watercourse		■			■		■	■		■	■		■	■	
	Wildlife	■	■	●		●										
	Aquatic fauna		■			■		■			■	■		■	■	
	Flora	■		●		•					•	■		●		
	Air quality		■	■					■						■	
	Soil	■	■	●		■		■							■	
HUMAN	Health			●	■	■		■	■		■					■
	Security		■		■		■	■	■	■						■
	Economy	■				■		■				■				
	Agricultural space	■	■			■						■				
	Forest area	■	■			■						■				

Legend: ■ = strong impact; ● = low impact; • = negligible impact.

3.6. Principles of Rehabilitation

In view of the observations made on the field we proposed to submit to RUSAL general principles of rehabilitation which are:

- **Profiling**

It represents the preliminary step required to stabilize the site, and ultimately to limit soil erosion. It also reduces the visual impacts of mining activities by integrating careers in the surrounding topography. During reshaping, the additional interference should be limited to the extent possible. Generally, profiling changes the background of careers and soils storage areas to make them parallel to existing topographical contours.

- **Erosion Control**

Erosion control measures are in place to reduce the flow of surface, limit sediment transport by runoff and allow the establishment of a vegetative cover on the site. Soil erosion at the edge of careers and re-deposition of soils within the quarries were found in places. The borders of careers will be profiled, as far as possible to fit the topographic contours.

- **Storage and replacing**

Soil in the future, soil careers, and access roads will be removed and either reused directly for rehabilitation, whether stored for use at a later rehabilitation, which is not the case. The first option has the advantage of avoiding double handling soil. There are a number of recommendations regarding the storage of soil. Storage areas should be as close as possible to the site where the soil will be reused to limit repetitions to manipulations, and in a place where they will not have to suffer from the effects of mining activities. The maximum inventory level should not exceed 2m to reduce compaction. The soil should be in place by successive vertical levels to reduce manipulation and degradation of the soil structure. Stocks soil should be promptly reforested to protect them from erosion and maintain active populations of microbes in the soil. Soils stored will be used during rehabilitation. They will be spread at the bottom of careers in natural thickness of soil in the Fria region.

Table 8. Situation of the areas restored by RUSAL

year	Area exploited (ha)	Restored Area (ha)	species planted
2002	11, 09	09, 77	E. AC. M.
2003	26, 35	23, 60	M. AC. P.
2004	11, 23	12, 10	E. AC. CA.
2005	15, 45	25, 70	E. AC. CA.
2006	20, 29	31, 60	E. AC. M.
2007	9, 61	32, 30	DP. AC. E.
2008	17, 26	30, 40	DP. AC. E.
2009	8, 17	15,70	P. AC. CA.
2010	13, 22	24, 99	C. AC. DP.
2011	12, 10	18, 03	AC. M.
Total	144, 77	224, 19	-

Legend: E (Eucalyptus); AC (Acacia), M (Mango tree); P (Parkia); C (Cashew); DP (Dwarf Palm).

This program seeks the restoration of a slightly wooded savannah in continuity with the current reforestation programs. So far, grasses are not sown, but will recover naturally. To speed up the restoration of grass cover and undergrowth and improve the soil water holding capacity, seed mixtures of grasses and shrubs belonging to those identified by the inventory of flora in the environmental and social impact study should be sown. The use of local species should take precedence over those foreign to the area in the rehabilitation project, as they can grow faster and inhibit the rehabilitation of local vegetation.

Preparations for planting

The preparations are aimed at restructuring the groundbreaking large clods caused by compaction to form a stable ground, not compacted, for seeds and plants. These preparations increase the availability of water for plants, improve rooting, remove weeds and promote contact between seeds and surrounding soil. The techniques used will be depending on the nature of the soil, sowing and planting methods, and climate. The areas which have been a very important compaction such as the pathways that are not currently rehabilitated should be pipes before being covered with a material suitable for the growth of plants.

Plant propagation

Methods that should be used will be: direct sowing either mechanical or manual (at sowing or stolen); display of cut plants on the ground, the use of this technique in Mali to restore a herbaceous cover was successful; plants from nurseries; transplanting individual plants of surrounding natural areas; transfer housing, namely, to avoid the transfer of large amounts of soil undisturbed with plants and organic materials; natural establishment of species around as already happened in quarries rehabilitated Fria.

Planting of tree species

Three months plants will be provided by nurseries and planted by the subcontractors selected by tender as a current practice. The Department of Environment will continue its quality control of supplied plants and services on the ground to ensure they meet the needs of RUSAL. The plants will be planted in holes 35 cm in diameter and 35 cm deep on a mesh 3 m x 3 m. after the plants in place, the holes will be filled with soil from the holes and/or soil previously stored. A small pond will be created around the trunk to accommodate the water.

Fertilizer application

Given the poverty of lateritic soils in the Prefecture of Fria, fertilizer application should be considered to promote the establishment and growth of vegetation. The good growth rates achieved in the 2003 reforestation campaign emphasize the value of fertilizers. For good plant growth, fertilizer should be applied in rehabilitated quarries in the three years after planting. Chemical fertilizers can be easily leached soils and affect the establishment of local plants and germination of pulses. Organic fertilizers will, therefore, be used wherever it is possible. RUSAL need do soil tests to determine the most suitable fertilizer.

Reforestation trials

Until now, the rehabilitation has resulted in the creation of a savannah of low biodiversity or mono-specific in most careers. Trials should be conducted to assess alternative strategies reforestation using both different species and species currently used in combination. These trials should be used to develop reliable and cost-effective strategies to increase biodiversity in rehabilitated quarries. Other studies can evaluate the different applications of fertilizer and/or mulch. The results of these trials might change the reforestation program if necessary.

Management of alien species

In order to limit the introduction of alien species in rehabilitated quarries, one of these species management programs should be implemented, including controlled burning and grubbing campaigns. The program includes field studies used to identify exotic species (e.g. eucalyptus) and the most appropriate physical, mechanical or chemical treatments to eradicate them.

Monitoring of rehabilitation

A follow-up should be set up to determine the success rate of the plants and the overall success of reforestation. The monitoring should include field studies during the first growing season after planting to evaluate the survival rate of plants. The establishment of exotic species should be monitored for at least two years. If their presence is discovered, a physical, mechanical or chemical should be implemented to limit their establishment.

In general, monitoring will take place twice a year at the end of the dry season and at the end of the wet season, for at least three years after the end of rehabilitation operations. The data will be evaluated to determine whether the objectives of rehabilitation were achieved. The programs will be continued or modified based on monitoring results. Three years should be sufficient to demonstrate compliance with the objectives of rehabilitation, monitoring will stop when the objectives have been achieved. The objectives of rehabilitation should be fixed agreement with all stakeholders during the public consultation process.

4. Discussion

4.1. The Activities of RUSAL Company

The environmental damage that is caused in the industries, in general, is due to the production process

used. The alumina plant of Fria is no exception to this rule. In doing so, the damage caused by the bauxite sector needs above all to go upstream, from the place where resources are produced following step by step which acts on the environment. All RUSAL activities have affected the different components of the environment but do not have the same degree. Preliminary prospecting activities to transportation dangerously affect the flora, fauna, watercourses and atmospheric air. Fragmentation and introduction of edge change forest structure, composition, and ecological processes [10,11]. As reported in the results, each of the sectors of production is linked to very harmful environmental damage that can be explained by the use of chemicals in the various workshops. Unlike the preliminary activities, it appears that the one negative impact begins with a high rate of pollution of the environment including groundwater, and some health-related risks. The factory of Fria rejects a tonne sludge per ton of alumina produced, which has a negative impact on renewable natural resources. Furthermore, this sludge is composed on average of 60% iron, 30% lime and titanium traces.

This is confirmed by Ruf, Thierry, [12] who reported that the extractive or mining activities, even rationally organized for the exploitation of the deposit, very often lead to degradation of environmental resources. These activities have a highly visible impact when conducted on the surface. Among the deposits mined by extractive activities are differentiated: underground mineral deposits; surface deposits, mineral deposits careers, alluvial deposits, construction materials quarries. Various other risks associated with mining activities namely: risk of accidental or permanent physical or chemical pollution; human concentration. Furthermore, Geny, [13] found that red mud from the alumina industry disfigures many land areas by their red cast solidified. They are an inorganic material, inert and sterile solid structure containing 40% iron oxide and 6% of sodium with a highly alkaline pH of about 11.

4.2. Impacts of Different Activities of RUSAL Company

The severity and extent of RUSAL activities depend primarily on the importance of exploited resources and secondly, on the type of resource that can generate specific pollution; may be mentioned the following cases: physical degradation of the environment; the unorganized tailings storage leads, reflecting important tropical rain erosion; chemical degradation, various types of pollution of surface water and groundwater; damage to fauna and flora around, land, and primarily their biology. A similar result has been reported by [14] for soil subject to emissions from various mining and environmental change plants in Sierra Leone. Direct impacts covered infringements of microflora and soil fauna with consequences induced on the fertility maintenance cycles. In the process of degradation of renewable natural resources in the area of intervention of RUSAL, the local population, by various socio-economic activities contributes to the worsening of this process by the fact that no steps towards the rational use of resources are envisaged in terms of area. A team from the World Bank led by WHO [15], in a report sought to place responsibility; according to that report, farmers, ranchers, the logging companies and mining company's firewood gatherers, each pursuing its interests with a misguided policy, sharing this responsibility.

According to WHO [15], the Aral Sea is dying. Over the past 30 years, its volume was reduced by two-thirds because of huge quantities of water which has been extracted there, particularly for irrigation requirements; its surface is greatly reduced, its water and that of the surrounding aquifers have become increasingly salty and health and water supply nearly 50 million people are threatened. By withdrawing, the sea has cleared vast tracts of low saline land and under the effect of the wind; the salt is deposited on farmland and neighboring pastures, with the environmental damage that we imagine. In the delta of the Amon-Dara, which feeds the Aral Sea, the number of days without frost fell below 180, the threshold below which the production of cotton, the main crop in the region is no longer possible. These changes were due to a fairly thriving fishing industry, and wildlife in the region is severely depleted. If nothing is done to counteract the ongoing evolution, the sea could be reduced to the dimensions of a salt lake in the equal sixth of what its area in 1960.

WHO [15] observed that attacks on human health undermine productivity and degradation of the environment, makes less productive many resources used directly by man; this is how the fishery product decreases with the water pollution, and agricultural yields suffering from saturation or salinization. The decline in productivity comes from damage to natural resources that man uses indirectly. In New Caledonia (Nickel mine), we find no vegetation on the cuttings consist of accumulated and compacted earth, very low permeability, resulting in a strong chemical runoff, the wastes are also a very hostile substrate [16].

4.3. Assessment of the Status of Renewable Natural Resources and Possible Threats

Stripping, blasting and blasting as well as key chemicals (caustic soda, acid, lime, and oil) represent threats to the components of the environment. The caustic soda increases the pH of streams representing a potential threat to flora and fauna, leading to the death of aquatic beings at a concentration of 54,4 mg/L inability to use alkaline waters of the river to water the gardens and the abandonment of the strip of land along the banks of rivers. In downstream of the tailings discharges, the concentrations of total cyanide and free cyanide in the rivers in the dry season were found to exceed environmental criteria for the protection of aquatic life [17]. The most important pollutant of the hydrosphere is acid (H^+) in the form of acid rain and acid mine drainage [18], also, generation and metals dissolution are the primary problems associated with pollution from mining activities which include the release of many chemical contaminants into water resources [19]. Local species and other strictly protected no longer exist in the project area, farmland is reduced, groundwater is deeply attacked following the infiltration of chemicals used by RUSAL. However, research has proved that the disfigured landscapes by cuttings and mining waste, damaging the environment, not only can be remodeled to reintegrate into

the landscape but can also receive herbaceous or shrubby vegetation or crops with the addition of nutrients and organic matter that can be found in other waste, particularly domestic and agriculture. Adjei, [20] found that much evidence that the community is heavily affected by gold mining activities in Ghana. Recovery is however not an easy process and requires many tests and substantial financial resources, even if the raw materials used are worthless. Chamayou et al. [21], confirmed that the caustic soda on the floor seeps and can harm agriculture as to plants and animals near and far.

Various tests, both in the laboratory and lysimetric box in the field; show that the red mud can be vegetated by mixing with sewage sludge, household waste or sawdust. It seems that these mixtures have been successful, the latter being an excellent structuring of the soil. Morphological examination showed good incorporation compost/minerals [13].

4.3. Restoration Made by RUSAL

Since his arrival in 2002, the company deploys enough effort for the restoration of renewable natural resources. But the finding reveals that society places more importance at reforestation careers at the expense of other resources such as soil, waterways, and wildlife. During the entire process, from the choice of species to the establishment in quarries, prefectural authorities (technicians) are rarely involved even less riparian population. While the involvement of these local people especially can be important for the effective achievement of the various operations, from which the participatory method. Participatory methods have three main advantages: they enable planners to better understand the values, knowledge, and experience of local people; they ensure the support of the population in favor of the project objectives and its support for the implementation on site; they can facilitate the resolution of conflicts over resource use.

The better environmental management is only possible if it is really desired by the government and desired by the general population. The recent experience of Burkina Faso on the occasion of the establishment of a national action plan for the environment illustrates how the process itself can help to raise awareness of the problems and generate the political necessary for any action [13]. The source affirms that this work has highlighted the actions in several key areas: developing the capacity of environmental management at all levels, improve living conditions in the countryside and in cities, ensure environmental management at the village level.

5. Conclusions

At the end of our research, the results showed that the activities developed by the RUSAL remain are a source of pollution and most of the renewable natural resources are affected. If the RUSAL company has had a positive impact on the socio-economic life of population of Fria by creating jobs and electrical service and potable water, more or less degrading impacts on rivers, fauna, flora and culture spaces caused by the stripping of land, the supply of sediment, the dust emission, discharge of waste water and soil vibration are mentioned. All these elements undermine the entire sustainable ecological system and affect the economic and social development; consequently, this leads to difficulties of the population to provide basic elements to good nutrition, clean water, a healthy immune short, economic and socially sustainable development. Unlike other partners who run the operating company, the RUSAL experiencing a significant advance over the reforestation of quarries with 144.77 hectares operated, 244.19 hectares have been restored by the company although the population is not involved in the selection of species to develop.

Our findings revealed that popular participation can provide assistance to afforestation, protection of fauna and flora, improvement of sewerage networks and the fight against floods. The population can provide the manpower and knowledge appropriate to remedy the consequences of environmental disasters and local knowledge of genetic diversity that is at the origin of remarkable progress in agricultural production. For this, the participatory method was used at all levels to enable the company to come to the local community for decision making regarding the restoration of renewable natural resources and the implementation of an effective environmental policy by the middle industrial.

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