REVEGETATION OF BAYER PROCESS RESIDUE DISPOSAL AREAS IN CVG-BAUXILUM

Hartmann, V., Rangel, O., Correia, M.
CVG-Bauxilum, Puerto Ordaz, Venezuela

Abstract

In 1998 CVG-Bauxilum started, as part of the environmental remediation process, a test program with the objective to find out how it will be possible to revegetate the areas actually used for process residue and red mud disposal.

Samples of the soil, laboratory analysis, investigation of previous experiences of revegetation of contaminated soils, were the basis for preparation of the pilot test, subsequently a field test and finally an almost 2.6 Ha experimental area, were we have at the moment growing species typical of this latitud. Several gramineous species were tested in a series of pilot areas, prepared with a different combination of fertilizers, sand, top soil and other chemicals. Only few of them grew successfully.

The strongest species whose characteristic is to grow on the surface and very resistant to climatic conditions were selected for the development of the experimental area, adequately prepared according to the best pilot section findings, with a sprinkler system to control the humidity during dry-wet season.

CVG-Bauxilum is confident to have taken a big step in the right direction environmentally speaking. Dust control and remediated area were achieved and will be the basis for future remediation of closed disposal areas.

1. Introduction

CVG-Bauxilum is a bauxite — alumina complex operating since 1983. Its current design capacity is 2.0 million tons per year of sandy alumina destined mainly to local market, while a 20% is offered on international market.

In 1998 CVG-Bauxilum started, an environmental remediation process and one of the projects was a study and test program to define a revegetation procedure in order to rehabilitate closed process residue and red mud disposal areas.

During 15 years the plant process residue as tank scale, contaminated hydrate or alumina, oxalate agglomerates produced during tanks cleaning were disposed on a 5 Ha area which was part of the sand pond.

The residue was disposed using trucks and payloaders until it reached 6 meters high with an estimated volume of 240 000 m^3 becoming an unstable and environmentally non acceptable disposal area. This area was closed and embanked and new areas at the red mud ponds were prepared for residue disposal.

Once a 2.6 Ha terrace was prepared, a revegetation study was initiated with two main objectives:

- Define which species can grow under extreme soil conditions.
- Develop an area environmentally in agreement with local regulations.

The study provided CVG-Bauxilum enough data related to the strongest species, how to prepare the topsoil conditions and chemical products to be used during the preparation, sowing and first growing periods. Also this area will provide data on a continuous basis for future revegetation on new closed deposition areas.

2. Site conditions

The general site conditions can be defined in two aspects

2.1 *Climatic conditions*

CVG-Bauxilum located in Puerto Ordaz, Bolivar State, Venezuela is a tropical area with a rainy season from may to september. The temperature varies from 17 to 41ºC with a relative humidity from 34 to 100%. The pluviosity varies from 5 mm to 370 mm per month with an east-west and north-east predominant wind.

2.2 *Soil conditions*

The soil conditions for this project is a mixture of plant residues with a pH above 10 with non uniform composition.

3. Pilot test

CVG-Bauxilum had no previous experience in revegetation of mud or process residue disposal areas, so after some investigation on work done in other plants a program was established as follows:

3.1 *Soil sampling*

The samples were gathered superficially and 20 cm deep in 6 different sectors. The superficial samples were classified as A and the deep samples as B. Twelve samples were prepared for the assay.

3.2 *Sample laboratory analysis*

The samples were analysed in the laboratory and also some tests were done with aluminium sulfate with the following results.

Table 1 — pH and treatment of samples from terrace

Sample	pH Initial	Amendment 21/11/98	pH 25/11/98
1A	10.07		10.46
2A	10.38		10.27
3A	10.77		10.63
4A	10.81		10.50
5A	11.36		10.80
6A	10.42		10.43
1B	11.18	Urea	10.08
2B	11.21		11.20
3B	11.38	Lime	9.90
4B	11.84	N-P-K	9.58
5B	12.05	Sulfuric,Chloridic, Phosphoric acid & Aluminium Sulphate	
6B	11.11	Humus	10.31

Characterization of the material sampled in the 10 sectors of the terrace

Sample %	Fe2O3	TiO2	CaO	SiO2	Al2O3	Na2O	Pb	Hum
1–8	17.8	1.5	3.9	28.4	30.1	4.67	10.3	8018
9–10	13.1	1.3	3.0	48.6	19.8	2.34	7.5	15.39

The application of aluminium sulfate directly to the mud sample in a proportion of 0.1gr per cubic meter of mud stabilized the pH between 7 and 8.

3.3 *Assay in a germination trays with amendment*

Samples were placed in a germination trays and pH was determined for each one (table 1). Fertilizer, lime, mixture of acids and aluminium sulfate, and humus were added in order to change the pH conditions of the samples. Sample 1A was seeded with Pueraria Phaseoloides and the rest of the samples with Cynodon Dactylon seeds.

The low permeability, high density of the samples and the pH conditions were too critical and no germination was observed.

A change on the assay procedure was suggested and a 34 Kg sample was prepared directly on the terrace. The sample starting pH was 11,35. An aqueous aluminium sulfate solution was applied neutralizing the sample to pH 6,8 immediately after the application. Four months later the pH was at 9,1.

After the aluminium sulfate was applied the sample was seeded with Cynodon Dactylon and Cynodon Nlemfuensis and four months later germination was observed. During that period some rain and manual watering was recorded.

3.4 *Field test area preparation*

In order to define the adaptability of the different species to the soil conditions and to choose the best one for further work, the following concept was proposed. Ten sectors of 5 × 5 m were prepared and each sector was subdivided into 4 equal sections identified 1A,B,C,D, etc. Each sector was prepared with different procedures, using a combination of soils, with or without geotextiles, with base soil compacted or loosened and seeded or sowed with different locally growing species (see table 2).

The objective of these combinations were to test the capilary migration of the pH and the influence of different soil qualities on the growing capacity of the selected species by means of the draining characteristics of each particular arrangement.

The basic aproach to this problem is not to insist too much on direct work with the mud and its amendment as many others have studied, but working with different top-soils which may control capilarity migration by isolating the contaminated soil from the topsoil and at the same time represent a less expensive solution.

3.5 *Application of assay results on the test area*

According to laboratory results, documentation of similar studies, suggestions given by experts in plant nursery, the following species were proposed for the field test.

Cynodon Nlemfuensis (Pasto Estrella)
Cynodon Dactylon (Pasto Bermuda)
Melinis Minutiflora (Capin Melao)
Bracchiaria Humidicola (Pasto Alambre)
Bracchiaria Decumbens (Pasto Barrera)
Cloris Gayana (Pasto Rhodes)
Paspalum Notatum (Grama Lengua de Vaca)
Pueraria Phaseoloides (Kudzu Tropical)

Main characteristic of this species is that they grow superficially and the roots do not penetrate very deep if enough nutrients are available in the topsoil. This introduces a requirement for periodical fertilization in order to maintain an equilibrium of nutrients.

The sowing and seeding of the different sectors was performed according to table 2. Few species were not available commercially and others were difficult to gather in the quantities required and were not used.

3.6 *Evaluation of results*

During the test period from april 1999 through november 1999 fertilization with NPK 14-14-14 or liquid and solid humus was performed according to the program established and watering was applied on a routine basis considering the amount of rain to avoid excess of water that can cause an increase of caustic migration to the surface.

After a period of eight months period the results showed that C. Gayana was the strongest and it was spreading into adjacent sections where other species died, therefor it was selected for the next step which is the revegetation of the 2.6 Ha terrace.

Table 3 presents the results in each particular sector, expressed as a percentage of success.

Table 2 — Revegetation test control table

Sector	Section	pHi 17/5/99	pHf 17/11/99	Sector preparation	Species selected
1	A		10.5	Clay loose sandy & organic topsoil	Bracchiaria Humidicola & Decumbens
	B	7.4	10.4		Rhodes, S. Purpureum, P. Notatum, C. Nlemfuensis, M. Minutiflora
	C				Cynodon nlemfuensis
	D				Cynodon Dactylon, Cloris Gayana
2	A			Sandy loose & black organic topsoil	Bracchiaria Humidicola & Decumbens
	B		9.6		Br. Humidicola & Decumbens, Cloris Gayana, Cynodon Nlemfuensis
	C	9.2			Idem 2 B
	D				C. Dactylon, Br. Humidicola, C. Nlemfuensis
3	A			Geotextile membrane, yellow sandy loose & organic topsoil	Br. Humidicola & Decumbens, C. Dactylon
	B	6.7	5.3		Rhodes, S. Purpureum. P. Notatum, M. Minutiflora
	C	7.4			Cynodon nlemfuensis
	D				Cynodon Dactylon
4	A	6.3	10.5	Yellow sandy loose	Bracchiaria Humidicola & Decumbens
	B				Rhodes, S. Purpureum, P. Notatum, M. Minutiflora
	C				Cynodon nlemfuensis
	D				Cynodon Dactylon
5	A	10.5	10.4	Sand from pond & sandy loose	Bracchiaria Humidicola & Decumbens
	B				Rhodes, S. Purpureum, P. Phaseoloides
	C	6.3			Cynodon nlemfuensis
	D				Cynodon Dactylon
6	A	10.5	10.0	Sand from pond & organic topsoil	Br. Humidicola & Decumbens, M. Multiflora
	B				Rhodes, S. Purpureum, P. Phaseoloides
	C	7.4	9.9		Cynodon nlemfuensis
	D				Cynodon Dactylon
7	A	10.5	10.7	Loosened base material, sand from pond & yellow organic topsoil	Bracchiaria Humidicola & Decumbens
	B				Rhodes, S. Purpureum, P. Phaseoloides
	C	6.7			Cynodon nlemfuensis
	D				Cynodon Dactylon
8	A	10.5	10.6	Loosened base material, sand from pond & organic topsoil	Bracchiaria Humidicola & Decumbens
	B				Rhodes, S. Purpureum, P. Phaseoloides
	C	7.4			Cynodon nlemfuensis
	D				Cynodon Dactylon
9	A	10.3	10.3	Loosened base material, Aluminium sulfate, lime & NPK 14-14-14	Cynodon Dactylon, Nlemfuensis
	B				Cynodon Dactylon, Nlemfuensis
	C				C. Dactylon, Nlemfuensis, M. Multiflora
	D				Cynodon Dactylon, Nlemfuensis
10	A	7.5	8.4	Same as 10 with double amount of aluminium sulfate	Idem as in 9 A,B,C,D
	B				
	C				
	D				

3.7 *Final revegetation on the 2.6 Ha terrace*

The 2.6 Ha terrace was divided in six sections of 53m by 70m separated by 4m width access.

The base material with a pH above 10 was covered by a 10cm layer of sandy type very loose material (not washed sand). On top of that a 20cm topsoil layer of organic material was used. The laboratory analysis indicated that the topsoil was slightly acid and with low phosphate content.

An automatic sprinkler system was provided for watering and is being adjusted for dry and wet season to avoid excess watering and reduce costs.

Before sowing the grass the phosphates deficiency was complemented with NPK 10-26-26 fertilizer. This procedure was repeated twice adding also urea, after the Rhodes grass (Cloris Gayana) was sowed in parallel rows separated by 5m and orientated east-west taking into account the predominant wind direction.

The survival by may 2002 is aproximately 80% of the sowed grass. It was trimed to help with the spreading of seeds considering the wet season started.

4. Conclusions

The revegetation project represents an important step for CVG-Bauxilum for the environmental remediation process, achieving a pollution control in an area located close to the industrial facilities.

A significant data is now available to continue the investigation with the support of local Universities and Investigation Centres.

Almost 3 years of investigation and field tests show that the revegetation of mud disposal areas is possible even in severe climatic conditions.

The productivity in sectors with loosened sandy soils and protected form the wind was higher, while the sectors with sand from the pond were less productive.

The sector isolated from base soil by a geotextile membrane was as productive as others without membrane.

The Chloris Gayana is the predominant specie on the terrace but other species appear naturally and will be monitored during next wet season gathering new data.

Table 3 — Results after 8 months expressed in percentage of success

Sector	Section	%	pHf 23/2/00	Sector preparation	Species identified in each section
1	A	2		Clay loose sandy & organic topsoil	Cloris Gayana
	B	75	9.0		Cloris Gayana, Cynodon Nlemfuensis
	C	100			Cloris Gayana, Cynodon Nlemfuensis
	D	5	10.2		Cloris Gayana, Cynodon Dactylon
2	A	80		Sandy loose & black organic topsoil	Braquiaria Decumbens & Humidicola
	B	90	10.2		Cloris Gayana, Br. Decumbens & Humidicola
	C	90			Cloris Gayana, Br. Humidicola & Decumbens
	D	90	9.5		B. Humidicola, Cynodon Dactylon
3	A	90		Geotextile membrane, yellow sandy loose & organic topsoil	Br. Decumbens & C.Dactylon
	B	90	6.7		Br. Decumbens & Humidicola, C. Nlemfuensis & Cloris Gayana
	C	90			Br. Humidicola, C. Nlemfuensis, Cloris Gayana
	D	80	7.0		C. Dactylon, Br. Humidicola, Cloris Gayana
4	A	70		Yellow sandy loose	Cloris Gayana, C. Dactylon, Br. Decumbens
	B	40	9.7		Cloris Gayana, Br. Decumbens, C. Nlemfuensis
	C	90			Idem 4 B
	D	40	9.7		C. Gayana, Br. Decumbens, C. Dactylon
5	A	10		Sand from pond & sandy loose	C. Gayana, C.Dactylon,
	B	10	10.2		C. Gayana, Br. Decumbens
	C	20			Cloris Gayana
	D	10	10.3		Cloris Gayana
6	A	20		Sand from pond & organic topsoil	Cloris Gayana, Br. Decumbens
	B	100	6.4		Cloris Gayana, Br. Decumbens, C. Nlemfuensis
	C	100			Cloris Gayana
	D	80	10.0		Cloris Gayana, C.Dactylon
7	A	1		Loosened base material, sand from pond & yellow organic topsoil	Cloris Gayana
	B	2	10.2		Cloris Gayana, C. Dactylon
	C	1			C. Nlemfuensis
	D	0	10.3		--------
8	A	75		Loosened base material, sand from pond & organic topsoil	Cloris Gayana, Br. Decumbens
	B	50	10.6		Cloris Gayana, C. Nlemfuensis
	C	50			Cloris Gayana, C.Nlemfuensis, C. Dactylon
	D	25	10.5		C Dactylon, Cloris Gayana
9	A	25		Loosened base material, Aluminium sulfate, lime & NPK 14-14-14	C. Dactylon
	B	10	10.6		C. Dactylon, C. Gayana
	C	80			C. Dactylon, C. Gayana
	D	30	10.2		C. Dactylon, C. Gayana, Br. Decumbens,
10	A	50		Same as 10 with doble amount of aluminium sulfate	C. Dactylon, Cloris Gayana
	B	95	8.2		C. Dactylon
	C	80			C. Dactylon
	D	60	10.5		C. Dactylon, C. Gayana

Note: The species are named starting with the more successful in each section.

REFERENCES

Bell, D. and Ward, S. (1992) Selection of trees for rehabilitation of bauxite tailings in Western Australia. An international bauxite tailings workshop, Perth (Australia).

Lisena, M. and Rangel, O. (1999) Revegetation essays in red mud. CVG-Bauxilum (Venezuela).

Nabalco Pty. Ltd., Gove, Australia. Revegetation essays in red mud disposal areas. Alusuisse edition.

Wong, J.W. and Ho, G.E. (1992) Viable technique for direct revegetation of fine bauxite refining residue. An international bauxite tailings workshop, Perth (Australia).