Applications of the Vetiver System
Technical Reference Manual
Biofilter Vetiver System

by Oswaldo Luque M.

Biofiltro Sistema Vetiver

SAVER 1343 C.A
Soluciones Ambientales Vetiver

Prologue

It is an honor to be asked to write a short prologue for this document. I have known my friend and colleague Oswaldo for more than 40 years, and I an deeply impressed by his capacity to devolope solutions to different kinds of problems present during his work. After four years of research in El Tigre-Anzoategui State-Venezuela, he developed a solution for the transformation a residue from the brewary into an organic fertilizer. That experience, besides his love for a plant called Vetiver, allowed him to continuosly improve many environmental solutions in the industry in Venezuela. These solutions, mostly veitver phytoremediation techniques, together with several small other adaptations has been applied with great success. Congratulations and continue advancing with more solutions.

Ing° Agr° PhD. Juan Comerma Gutierrez.

APPLICATIONS OF THE VETIVER SYSTEM, TECHNICAL REFERENCE MAUNAL
BIOFILTER VETIVER SYSTEM

Oswaldo Luque M. SOLUCIONES AMBIENTALES VETIVER 1343 C.A (SAVER1343 C.A)

ABSTRACT.

The Biofilter Vetiver Systema (BVS) is waste reclamation technique base on the incorporation of the Vetiver (*Chrysapogon zizanioides* (L) Nash) to the methodology called early as Biological Aeration Filter. There is a chapter that describes it in detail, technical, scientific aspects, construction and operation system, used at industrial areas in Venezuela. The BVS has been in uninterrupted operation for more than 23 years in some factories. It has been used for odor control, brewery sewage sludge processing, degradation of products not suitable for human and animals' consumption and their environmentally safe disposal, treatment of residual waters instead of Conventional water wasted treatment plant and recycling in agriculture of non-dangerous organic waste.

THE ORIGIN AND HISTORY OF BIOFILTER VETIVER SYSTEM. (BVS) Estearn Polar Brewery "Cerveceria Polar de Oriente" (Photo1), as a result of the star-up the wastewater treatment plant in 1978 (Photo2) began to generate about 40,000 kilos of brewery residuals sludge every day, which were difficult to dispose adequate and environmentally safe. Faced with this problematic, "Fundación Empresas Polar", representing the Brewery, agrees with the National Fund for Agricultural Research (today called INIA) scientific research for the brewery sludge recycling in agriculture. (Convenio Fundación Polar-Fonaiap,1981).

Photo 1: Polar Brewery Plant
10° 7´11.13´´N; 64° 36´21.91´´W

Photo 2:Brewery Wastewater Treatment Plant
10°78.00´´N; 64° 38´28.04´´W

Photo 3: CEPAREL
10°6´44.43´´N; 64°39´59.92´´W

The author of this paper was the responsible for carrying out this research during 4 years (1983-1986) on sandy soils (Ultisols) in "Mesa de Guanipa" (8°54´08" N;64°11´91" W) representative of 3.000.000 of hectares (Luque, O, 1986). The results obtained were excellent and, consequently; were applied to Polar Center Brewery and Polar Model Brewery (Photo 1), those had the same problem with the brewery sludge disposal. The author proposed to the Eastern Brewery, founded and directed the Center for Processing Brewery Residual Sludge (CEPAREL) (Photo 3) on a three hectares plot in the industrial area of "Mesones "Anzoátegui State. (Luque, O, 1994). The objectives were produced compost and continue the research for recycling other wastes from the Brewery and support graduate students' theses and communities in this area (Teaching people about family agriculture). The system used in CEPAREL was known as Beltsville Aerated Pile Method, (USDA and EPA, 1980).

It consists of ad-mixture of woodchip with brewery sludge and it was collocated over a performed pipe connected to extractors systems in order to make vacuum to work in aerobic system, the runoff water was collected and store in metallic tanks. This process was reverted due to operative problems and started to use to spread the residues in the land with compost and applied the runoff for treatment. The material was put on the pile and after 21 days was collocated in maturation pile for 30 days more and then passes to the screening system. Bad odors generated by the residues processing, led the author to develop the methodology known as Extended Biological Filter for Extended Aeration. The vetiver technology was adopted in 2001 as the results published by Truong and Hart (2001), to contribute to water runoff treatment, later was named as Biofilter System Vetiver (BSV). The CEPAREL production was in average of 2,000 tons of compost/year, used for gardens, golf campus and others. It was opened in 1992. until 2018 as the main company ceased operation.

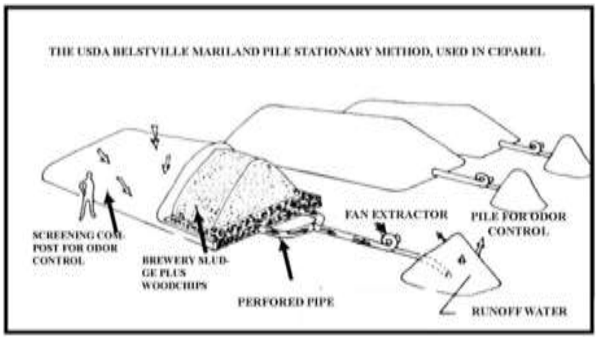


Photo 4: USDA Beltsville Maryland Stationary Pile used in CEPAREL

Photo 5: Harrowing to give aeration of BSV

BIOFILTER SYSTEM VETIVER (BSV) DESCRIPCION

Biofilter Vetiver System. (BVS). is a combination of bioremediation and phytoremediation technologies based in some principles taken from Land Farming System approved by Environmental Protection Agency (EPA) of USDA. The author made some modification, which uses the superficial soil as base cover by a 20-centimeter-wide compost layer, in a land at least 1.000 m^2 surface with a 1 % slope. The process starts with application of any of these contaminants: sludge, organic liquid, runoff water with high organic load or substances not useful for food or drink human or animal purposes. The objectives of the System were to transform those substances into innocuous products. Immediately, after the contaminants were on the compost was applied a mechanical aeration system with several harrow passes pulled by a tractor was applied. (Photo 5), at least one time a day.

Photo 6: The disc harrow was more efficient in the process

Photo 7: The hardpan was formed at 10-15 cms depth

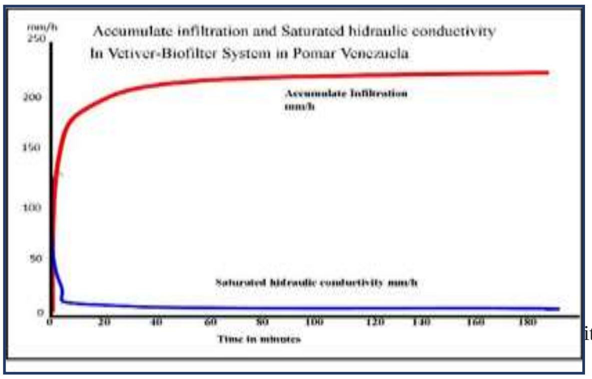
It has been proven that when the harrowing operation is passed several times over the soil, the hardpan-floor occurs at about 10-15 centimeters deep. It is a very dense compacted layer (Photo 7). This layer prevents the movement of the drainage water towards deep horizons, avoiding aquifers contaminations. This soil characteristic is very useful and it is not necessary to put plastic layers to waterproof deep horizons, which is very expensive.

Photo 8: Thin section of soil in natural condition

Photo 9: Thin section of soil sample disturbed by harrowing

This behavior is typical in soil with no tillage or minimal tillage, note the abundance of pores of various sizes (Photo 8), In the fine section of the tilled soil, a very poor pore distribution is observed (Photo 9). This notably reduces water infiltration to deeper horizons (Truouse,1971).

To check the hydraulic behavior of the BVS, an infiltration test was carried out with the cylinder method. Hydraulic Soil Characteristics (Photo 10) in the Biofilter Vetiver System. This is a test to demonstrate the low permeability by the presence of hardpan of the soil undergoing aeration practices.



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The cylinder method (Photo 10) was used to draw the Accumulated Infiltration rate and Saturated Hydraulic Conductivity (Photo 11), note that such tends to zero (blue curve) in very short time water passing through the subsurface horizon, above the hardpan, and it stabilizes, the water stops infiltration. It proves the effectiveness of the method. This test was replicated 5 times in all the Biofilter with the same results. The aeration effect is complex, but it can be demonstrated by the oxide-reduction reaction. The system is completed liberated of bad odors, and the transformation of the contaminants is rapidly discomposed.:

Without aeration, the system was totally anaerobic, and bad odors affected at least one square kilometer around the industrial area. Pölhe et al., 1993) describe that the main components causing this phenomenon at these sludge processing sites depend on the decomposition phase as reported in Table N° 1

Table 1: Odor active substances and determining odor impresión related to descomposition phase

Decomposition phase	Characteristic odor-active substances	Determining odor impression	Concentration (OU/m^3)	Period (days)	pH value
I. Acid starting phase	Aldehyde, alcohol, carboxylic acid ester, ketone, sulfide, terpene	Alcoholic — fruity	6000–25,000	3–14	4.3–6.0
II. Thermophilic phase	Ketone, sulfide-organic compounds, terpene, ammonia	Sweet — fungoid, annoying — musty	1000–9000	4–14	Limit to the basic range
III. Cooling phase	Sulfide, terpene, ammonia	Musty — fungoid — pungent	150–3000	To the end of the test period	–

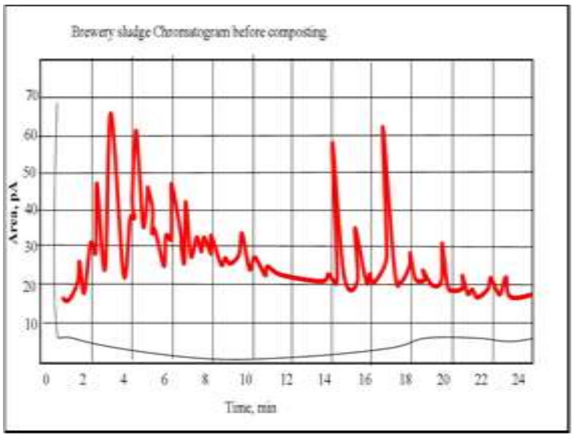


Photo 12: Brewary sludge extract Chromatogram before composting

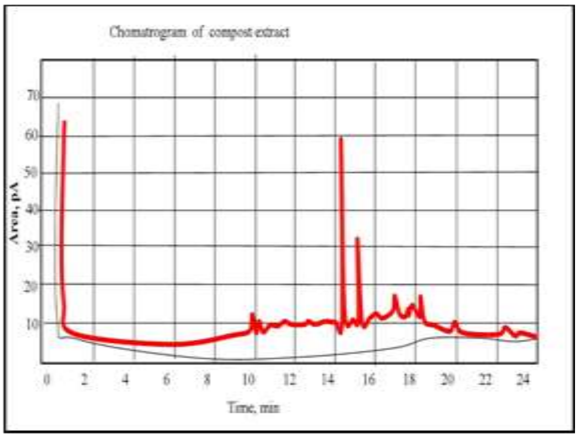


Photo 13: Chromatogram of extract after composting

HPLC (High-Performance Liquid Chromatography) carryout in a Polar Biotechnology Center on two samples; one, from an extract of residual brewery sludge (Photo 12) and the other is a sample of the composted sludge in CEPAREL (Photo 13). The organic compounds disappear (sulfides mercaptans and others), and there is an NH3+, which means that there are considerable amounts of other inorganic compounds useful as plant nutrients as Table 2 shows. Why vetiver? The BIOFILTER SYSTEM VETIVER model was conformed originally in a 1.000 m^2 (50 x 20 m), with 1 % slope, and two vetiver rows at the end to clean the runoff water drained towards the lowest parts of the land. Truong and Hart (2001) concluded that: Vetiver can be established in different environments and is efficient and low-cost method for treating effluent and leachate from both domestic and industrial source. for this reason, vetiver was included in the system to close the cycle of water treatment from runoff passed through the vetiver rows.

Table 2. Chemical analysis from brewery sludge and leachate water after vetiver

SLUDGE		Leachate after vetiver edges
pH	7	6.
COD mg.L^{-1}	500	70
BOD_5 mg.L^{-1}	450	12
Suspend solids	-	< 10
COMPOST		
Organic matter %	25	Not detected
Total Nitrogen mg.Kg^{-1}	1,700	< 50 mg.L^{-1}
Total Potassium	2,450	< 40 mg.L^{-1}
Total Phosphorus, mg.Kg^{-1}	1,225	<10
Total Calcium, mg.Kg^{-1}	13,800	Not detected
Total Magnesium, mg.Kg^{-1}	489	<0,01 mg.L^{-1}
Total Cupper mg.Kg^{-1}	0,88	<0,02 mg.L^{-1}
Total Zinc, mg.Kg^{-1}	4,4	< 0,05 mg.L^{-1}
Total Iron, mg.Kg^{-1}	6,4	<0,05 mg.L^{-1}
Total Manganese, mg.Kg^{-1}	5,3	Not detected

Note: *P and K extracted with NH_4F 0.03 N-HCL 0.002 5N (Bray 1), compost: extraction solution 1:10. Magnesium and Calcium extracted with MORGAN modified. Organic matter wet combustion (Walkley & Black). Cu, Zn, Fe, and Mn extracted with (HCL 0.05N –H_2SO_4 0.025 N). Black et al (1965). These methods are cited in American Society of Agronomy (1965) Water analysis by ASTM Standard Methods..

Table N° 2 Shows chemical analyzes obtained in sludge samples, compost, and runoff waters after vetiver rows. It is to notice that even when there is a significant reduction in the elements, mainly nitrogen and phosphorus, as well as the Biological Oxygen Demand (BOD5 and Chemical Oxygen Demand (COD). The data obtained from compost with the runoff water were not comparable, due to the fact that to carry out the compost analysis, established methods were used for the fertility soils analysis, and the analyzes of runoff waters were direct without the use of extractants, but in summary, it can be said that the water passed vetiver rows considerably lower the pollutants and return clean to the environment.

Truong, P and Truong N. (2011), have established that vetiver is tolerance to severely adverse conditions and elevated and sometimes toxic level pollutants, for instance, the vetiver is highly tolerant to soil high in acidity, alkalinity, salinity, sodicity, and magnesium, aluminum, manganese, arsenic cadmium, chromium, nickel, lead, mercury, selenium and zinc in the soil, capable of withstanding extremely high N supply (10.000 Kg/N/ha/year, and P (1.000 Kg. N ha/year, responding to very high N supply, high efficiency in absorbing dissolved nutrients, particularly N and P in polluted water, high-level tolerance to herbicides and pesticides (Diuron or Atrazine). Vetiver is drought tolerant and thrives under hydroponic conditions. High rates use water under wetland conditions.

For this vetiver behavior, the author considered incorporating the plant as a standard in the Biofilter named as BIOFILTER VETIVER SYSTEM. And the final design proposed was at least a rectangle of 50 m x 20 m, bounded along four rows of Vetiver, surrounded by drainage channels, two on each side, and a Vetiver wetland at the end of the slope, at least 12 rows. (Figure 2)

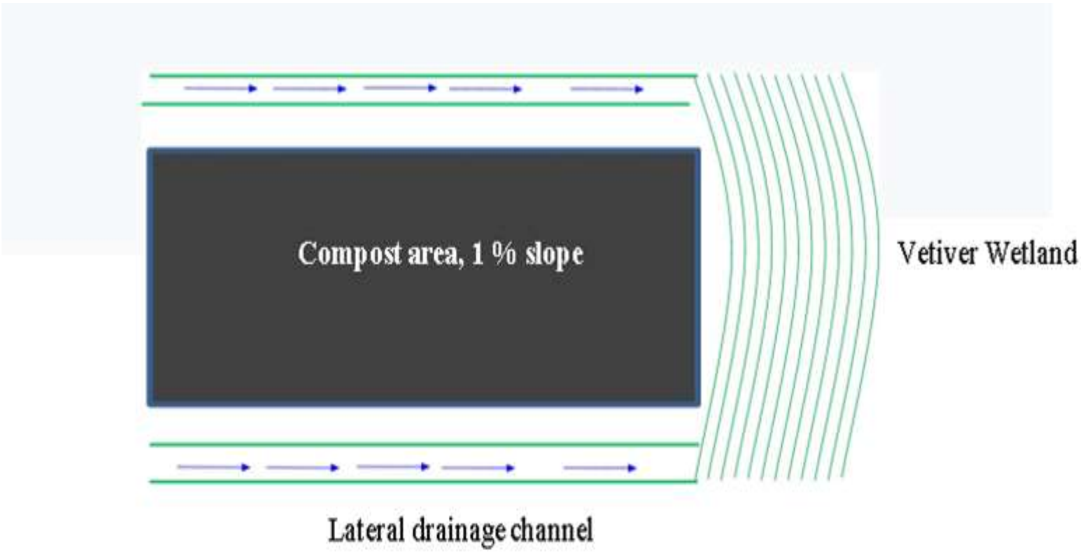


Figure 2. Biofilter System Vetiver scheme

CASE STUDY ONE. Pepsi-Cola discarded beverage.

During the years 2002-2003, there was a strike in Venezuela, which was called an oil strike (“Paro petrolero”), for these reasons more than 2,000,000 liters of soft drinks were withdrawn by Polar from the market as unsuitable products. Due to high sugar content, it was impossible to treat them in wastewater treatment plants due to the high consumption of electrical energy required. The author proposed the BIOFILTER VETIVER SYSTEM to treat them, and it was built at the Venezuela Pepsi cola Plant located in Tocoron, Aragua State. The liquid was stored in stainless steel tanks and from there pumped to the BSV area through a sprinkler irrigation system. The losses due to runoff were very low; however, the area was rounded with the vetiver lines and wetland, according to the design shown in figure N° 2. The results were excellent the microorganism in the compost layer of 20 centimeters transform the sugar at least in two days. The aeration was applied with a harrow pulled by tractor every day, and the typical reaction was:

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2\nearrow + 6H_2O\nearrow \quad \Delta G^{\cup}_{R} = -677 \text{ Kcal/mol}$$

Photo 14: Location of BSV at Pepsi Cola Tocoron Plant 10° 7´13.27´´ N; 67° 35´40.86´´

The BVS was working for three years, only stopping during the rainy season (3-4 months). The compost layer was 20 tons/hectare, at the end of the biodegradation process the compost was distributed to the farmer land.

CASE STUDY TWO. “Bodegas Pomar” (Winery)

Pomar winery belongs to Polar Enterprises, located at Carora State-Venezuela. (10°09´28´´N; 70° 05´15´´W). It comprises a vineyard of 30 hectares of the surface where grapes of the varieties Tempranillo, Syrah, and Petit Verdot, Chenin Blanc, Macabeo, Malvoisie, Malvasia Istra, Muscat D´Petit Grain, and Moscato Blanc are grown. The geographical location is (10°19¨55´´N; 70°,11´26´´W). With the experience gained at CEPAREL, the author was asked about the possibility of building a Biofilter System Vetiver, to treat contaminated water from grape processing. Once environmental permits were obtained from the relevant authorities, it was built in 1.993.

The system was initially used to treat wastewater from the wine factory, over 1.200 square meters, (Photo 15) the water was applied with a sprinkler system, on the ground, all the organic residues of the grape process were applied (rachis, seeds, yeast remains and other). This continuous practice was forming a compost layer on the ground surface, which contributed to improving the treatment of applied wastewater. The aeration was also frequently applied with a disc harrow pulled by a tractor. The water surplus that drained towards the lower part of the Biofilter was collected by a channel at the end and pumped back to the tanks that initially received the water from the wine factory. With the results obtained by Truong and Hart (2001). Vetiver was incorporated as a wetland; the results were excellent all the wastewater was treated in the system (BIOFILTER VETIVER SYSTEM) and there were no more runoff waters. At the end of the second year after vetiver wetland (2003); 300,000 kilos of compost were removed from BSV and applied to 30 hectares of vineyards (Photo 16), as part of the fertilizer grape process. Part of this compost was used as an activator of the 800,000 kilos of branches coming from the pruning of the grape plants; it is also used in the production of the vineyards. In conclusion, the BSV is

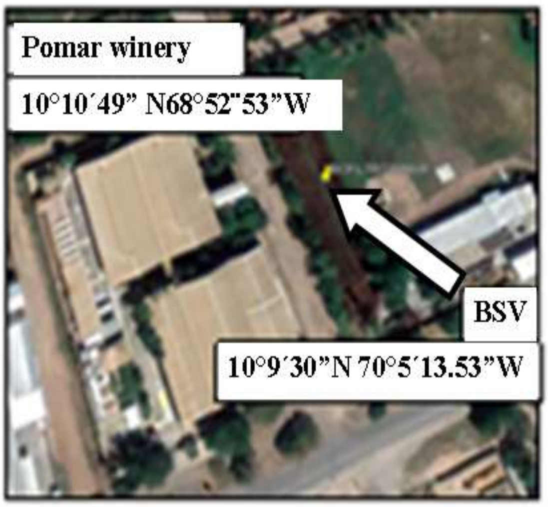


Photo 15: Location BSV and. Winery

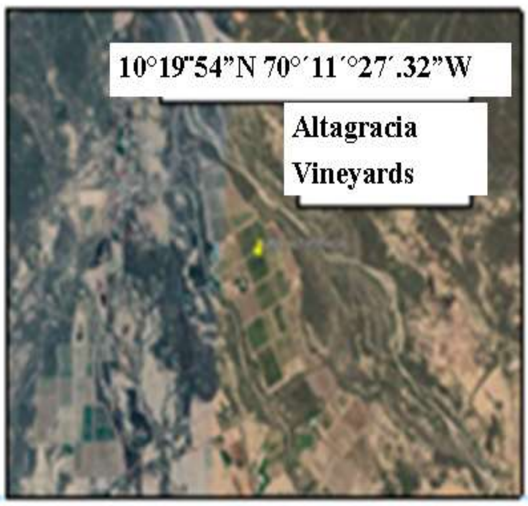


Photo 16: Viña Altagracia Vineyards

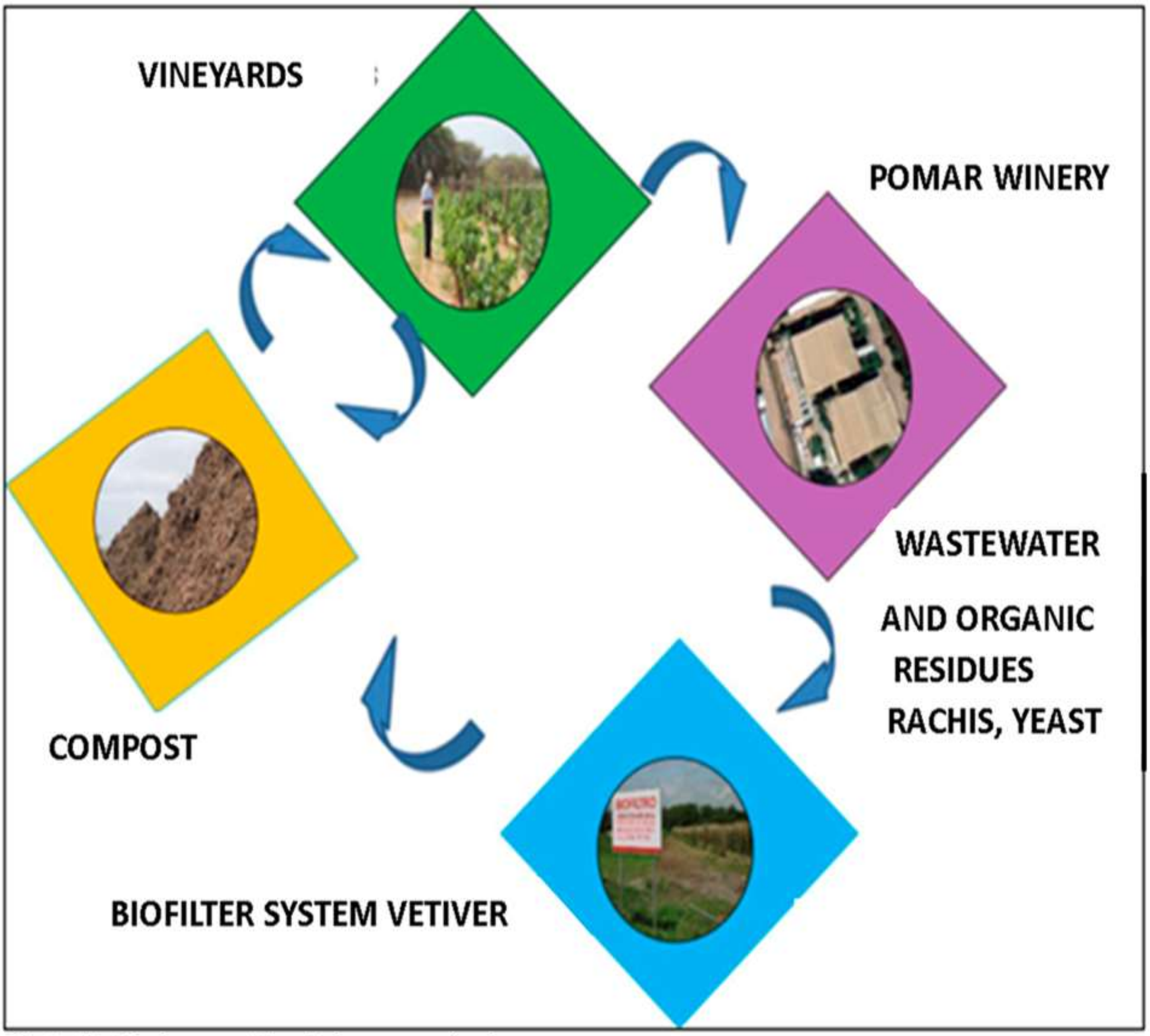


Photo 17: Environmental cycle in pomar wineries

The continuous use of compost in the winners improves the general soil conditions and created excellent environmental water- soil- plant. It permits to change of ammonium sulfate for urea in the drip irrigation system. Once the urea diluted in the water falls into the compost, the urease enzymes decompose this to NH3 and immediately is transformed into NH4 (ammonium), it is a cheaper and efficient way to fertilizer in the vineyards.

. Weather conditions at the Carora region of Torres district where BIOFILTER SYSTEM VETIVER is, are about 400 mm of rain a year, Average air temperature of 27°C, and Potential Evapotranspiration of 700 mm. /year. It is typical of arid regions. (Andrade, O-Benitez, 2012). These weather conditions are very favorable to the operation of BSV.

Photo 18 shows different aspects of operation Biofilter Vetiver System at Polar Wineries. This system was activated in 1993 and still is safe and in good condition.:


Biofilter Vetiver System.(VBS) .

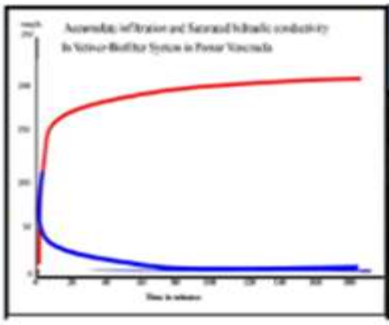

Wastewater Receiving Tank Reception (pool)


Rachis, and other organic waste


Irrigation Biofilter System Vetiver


Harrowing operation

Hardpan (red) formed by continuous harrowing


Infiltration curve, not water in depth


Vetiver wetland at the end of BSV


Vetiver at the border of BSV


Compost preparation in vineyard


Appling compost to grape (1kg/plant)


Pomar Staff training in BSV

Photo 18: Graphic aspects of the various operations carried out in the Pomar BSV.

CHEMICAL ANALYSIS OF WATER AND COMPOST IN BSV.

Tabla N° 3. Chemical analysis from BSV. It is a three months average, in different areas of Biofilter

pH		Total Suspend Solids			COD (Chemical Oxygen Demand)		
Reception tank (pool)	Runoff before vetiver wetland	Reception tank	Runoff before Vetiver wetland	After Vetiver wetland	Reception Tank	Runoff before Vetiver Wetland	Runoff after Vetiver Wetland
6.72	7.37	418.23 mg/L	249.7 mg/L	28.4 mg/L	10,833 mg/L	4,072.7 mg/L	2,850 mg/L

Table N° 3. Shows different analysis from water passed through the BVS, and some positive reactions of vetiver wetland. Water pH increase in the BSV due to different organics materials in the surface of Biofilter. Total suspended solids diminish by about 93 % and COD diminishes by 73,9 % when water passed through the Vetiver wetland.

Table 4, reports fertilizer chemical analysis from samples at the field irrigation campus of the BIOFILTER VETIVER SYSTEM (M1, M2, M3, M4)., M5 was sampled outside of Operational Area, in original soils, after vetiver wetland. The contents of Organic matter were very high; nitrogen, phosphorus, and potassium were high; the interchangeable bases: calcium, magnesium was low and very low, except the sodium content, which was very high it coming from the wine factory wastewater. The high sodium content in M5 is explained by genetic origin. The cations ratio was a very good indication of the availability of the secondary nutrients for grape, for example, the Ca/Mg ratio >10 shows a deficiency of Mg; the samples M3 and M4, meet this parameter to be a deficiency in Mg. The Mg/K ratio is <1 Mg deficiency so M1, M2; M3, M4 meets this parameter. >18 deficiency in K. Ca/K ratio >30 K deficiency. Ca+Mg/K > 40 K deficiency. Those interpretations are useful for the compost at vineyards for grapes. The Vetiver wetland (M5) are very interesting, shows very good and healthy vetiver plants. A good filter of the water and Calcium high and sodium values came from the genetic soils. The water at the end of the wetland was completely clear and the Totals Suspended Solids were very low with a % decrease of 87,7 %.

Table N° 4: Compost Chemical análisis from BSV-Operational Area Vs Original Soils in the Vetiver Wetland

Samples from BSV Operational Area					Original Soils
ANALISIS	Site M1	Site M2	Site M3	Site M4	Site M5
pH saturation extract	7.2	7.6	7.5	7.8	7.2
% ORGANIC MATTER (W&B)	68.25 VH	61.77 VH	64.13 VH	49.17 VH	2.51 H
NITROGEN %	2,11 VH	1,92 VH	2,06 VH	1,62 VH	0.21 L
CE mS/cm Saturation extract	3,17 H	2,10 M	2,85 M	2,81 M	27.3 VH
PHOSPHORUS ppm (OLSEN)	950 H	875 H	1040 H	1060 H	18 M
Potassium, (NH_4OAc 1N) ppm %	20,750 2 % VH	13,960 1.39 % VH	17,900 1.79 % VH	11,100 1.11 % VH	145 M
Carbonates (Collins) %	6.2	15.3 H	8.9 H	17.5 H	1.9 B
Interchangeable bases (NH_4OAc 1N)					
Calcium me/100 g ppm	0.68 L 136	1.06 L 201.46	0.84 L 168.3	1.01 L 202.4	25.5 VH 5110.2 VH
Magnesium me/100 g ppm	0.13 VL 15.8	0.14 VL 17.02	0.14 VL 17.02	0.12 VL 14.6	6.49 H 789.2
Sodium me/100 g	1,940 VH	3,250 VH	3,490 VH	4,400 VH	2.2 H
Micronutrients					
Iron ppm	16.8 L	17.2 L	16.0 L	19.5 L	2.2
Copper ppm	1.0 L	0.4 L	0.6 L	0.2 L	0.3
Zinc ppm	0.3 L	0.1 L	0.2 L	0.1 L	5.4
Manganese ppm	1.4 VL	1.0 VL	1.5 VL	1.1 VL	24.0
Relationships in Management and Soil fertility					
SAR (Sodium adsorption ratio)	1,077 VH	1,483 VH	1,772 VH	2,069 VH	
Ca/Mg	8,6	9,8	23.97 Mg deficiency	13.86 Mg deficien-cy	6.47
Mg/K	0.01 Mg deficiency	0.01 Mg deficiency	0.01 Mg deficiency	0.01 Mg deficien-cy	32
Ca/K	0.01 K deficiency	0.01 K deficiency	0.01 K deficiency	0.01 K deficency	
Ca+Mg/K	0.01	0.02	0.01	0.02	

Ca/Mg> 10 Potasium deficiency   Ca/K > 18 Potasium deficiency   Mg/K < 1 Magnesium deficiency
Ca+Mg/K > 40 Potasium deficiency   VH=Very high, H= high, M= médium, VL= Very low

CASE STUDY THREE, Alimentos Polar "Chivacoa" (APC)" (Polar foods)

"Alimentos Polar Chivacoa" (APC) Polar food "Chivacoa" is a company that produces "Harina Pan" it is flour to make "arepa", their daily bread for Venezuelan people. It is a versatile savory snack that can bake, fried, or grilled.

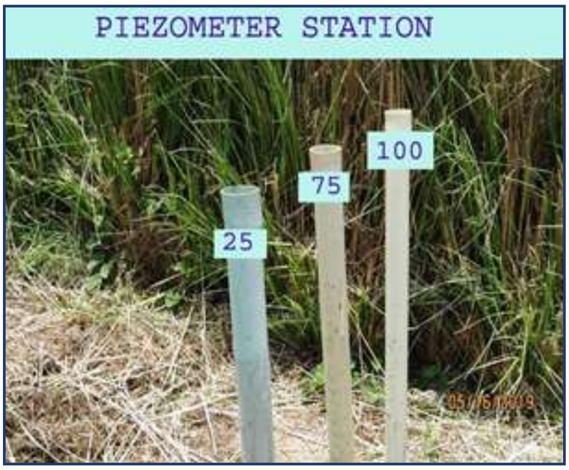
Photo 19 General view of BSV and APC Plant.

Given the positive experiences with the Biofilter System Vetiver, the author was called by APC to study the possibility of building a Biofilter on the land of the food processing plant (APC). The construction of the BSV began to be built in 2015, on a land of 1000 square meters (20 meters wide x 50 meters long) with a longitudinal slope of 1%. However, compost was not applied for operational reasons, and different organic materials began to be placed on the ground: sludge from the wastewater treatment plant, pruning remains from gardens and biodegradable waste materials from the industrial process. The aeration process was applied with the harrow pulled by the tractor with a daily frequency. This guaranteed the biodegradation of organic waste, without problems of bad odors, water aquifers contamination, or runoff water. Two years later, an evaluation of the organic component was carried out, detecting the presence of compost in a layer 20 centimeters deep. In this Biofilter, four rows of vetiver were planted along two drainage channels of the system to capture the surface waters that moved laterally, as well as a vetiver wetland, which was planted at the end of the Biofilter. Three piezometers were also included to monitor the possibility of movement of water to deep horizons. They were placed perpendicular along the terrain at 25 cm, 50 cm, and 100 cm depth. Until now, no water in these system have been detected.

Photo 20: BSV general view

BSV tractor harrowing operation

Photo 21: BSV 2 vetiver lateral row (A), (B) Operational area



Piezometer Station area for leaching depth measurement in cm.

Photo 22: Vetiver Humedal area

Compost area for use in garden

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The Biofilter System Vetiver is a technique created by the author of this Technical Manual. To recycle non-hazardous organic waste from the Food and Beverage Industries, and has been successfuly operated from more than 20 years, at many companies in Venezuela.

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