Transformando Residuos de Aguas Residuales en Fertilizantes: la planta de compostaje de Agropolo Campinas-Brasil

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Resumen:

Agropolo Campinas-Brasil fue creado en Campinas, Brasil como una plataforma colaborativa entre algunas instituciones públicas (Instituto Agronómico de Campinas-IAC, Universidad Estadual de Campinas-UNICAMP, Instituto de Tecnología de Alimentos-ITAL, Prefectura de Campinas y TECHNO PARK) con el objetivo de cambiar la forma de hacer investigación y promover innovaciones tecnológicas en el área de la bioeconomía tropical. Este artículo presenta el Proyecto de Compostaje (Usina Verde) creado por el consorcio IAC-Prefectura de Campinas-SANASA-CEASA. El objetivo de este proyecto es promover el compostaje con los residuales verdes urbanos y los efluentes de las plantas de tratamiento de aguas residuales de la ciudad de Campinas, Brasil. El composto resultante es usado como abono orgánico en la agricultura de la región.

Palabras clave: Agropolo, residuales, compostaje, biofertilizante.

Transforming Sewage Residues in Fertilizers: the Agropolo Campinas-Brasil compost plant

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Abstract:

Agropolo Campinas Brasil was created in the City of Campinas, Brazil as a cooperative platform between public institutions (Agronomic Institute of Campinas-IAC, State University of Campinas-

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UNICAMP, Institute of Food Technology-ITAL, City of Campinas, and TECHNO PARK) with the objective to promote technology innovation in tropical bioeconomy. The present article aims to present the Compost Project (Usina Verde) developed between the IAC, City of Campinas, SANASA Water and Sewage Treatment company of Campinas, and CEASA wholesale market. The objective of this project is to recycle mainly green urban residues with sewage mud to produce organic fertilizer.

Key Words: Agropolo, residues, composting, biofertilizer

1. INTRODUCCIÓN

The Agropolo Campinas-Brasil[7] cooperative platform was created in 2015 with the objective of introducing a different interdisciplinary research approach, focusing on higher value products.

The Agropolo Campinas-Brasil is an initiative of the following institutions:

- The Agronomic Institute of Campinas-IAC (www.iac.sp.gov.br)
- The State University of Campinas-UNICAMP (www.unicamp.br)
- The Food Technology Institute-ITAL (www.ital.sp.gov.br)
- The City of Campinas (www.campinas.sp.gov.br)
- TECHNO PARK Campinas (www.technopark.com.br)

Investigators from different institutions would have a common objective to overcome existing difficulties aiming a final product with quality and sustainability.

The City of Campinas with a population of 1.2 million habitants, situated about 100 km from São Paulo City and is considered the second economic pole in the State, the most developed in Brazil. Campinas is a traditional city in agronomic research with institutions such as the Agronomic Institute of Campinas – IAC with more than 100 years of existence. Campinas is considered the third best business, research, and innovation environment in Brazil.

[7] http://www.agropolocampinasbrasil.org/

In the Agropolo *Roadmap* conducted few years ago the area of Agricultural and Urban Residues was considered of high priority (Cortez, 2019; Carbonell et al., 2021a, 2021b, and 2021c). Agricultural residues in the city may have different sources, including material collected from houses, streets, and gardens. The city also has several sewage treatment plants producing important quantities of sewage mud. With the objective of using these materials was conceived the Compost Project between IAC-City of Campinas-SANASA-CEASA Campinas.

The motivation was to recycle residues and their use in agriculture is related to fertilizers. Particularly after the Russian-Ukraine War there was a sudden rise in the costs of fertilizers in Brazil. The country imports considerable amount of fertilizers from Russia, Canada, China, and Nigeria and depend on these inputs to satisfy the needs of growing agribusiness sector (Zafalon, 2022$_a$ and 2022$_b$).

Therefore, the present Agropolo Compost Project represents a great hope not only for the environment but also to alleviate the dependence of producing fertilizers from fossil fuels.

2. The Compost Project Stakeholders and Responsibilities

The City of Campinas, through its Secretary of Public Services, is the responsible for the Compost Plant technical operation. The Secretary has a specific contract with an engineering company contracted to manage the plant operation.

The Agronomic Institute of Campinas - IAC is the responsible to execute the laboratory analysis to control and monitor the biological processes that integrate the composting process. The IAC also authorized the use of an area inside the Santa Elisa Farm to implement and operate the Compost Plant.

The SANASA Water and Sewage Company is the responsible for the acquisition of equipment related to the Compost Plant (grinder, composter, and screen). SANASA maintains an engineer to contribute technically to maintain the equipment and operate the Compost Plant. There is also the participation of CEASA Campinas, the main fruit, vegetable, and flower wholesale market in the metropolitan area of Campinas. The CEASA Campinas will also provide residues to the project.

The Project Operation Team is composed of Eng. Alexandre Gonçalves - Director of Urban Cleaning Dept. - The City of Campinas, and Eng. Matias Oliveira Santos -SANASA, Responsible for the Compost Plant operation.

3. The Compost Project Description

The main objective of the Compost Project is to operate an organic residue composting system based on green residues obtained by municipal trimming and green areas gardening service, sewage mud from SANASA sewage treatment stations, and residues of fruits, vegetables, and flowers from CEASA wholesale market.

The sewage mud is produced by anaerobic treatment using UASB reactors originated from two SANASA sewage plants: Sewage Treatment Plant (ETE) of Capivari River, and Sewage Treatment Plant (ETE) of Piçarrão River.

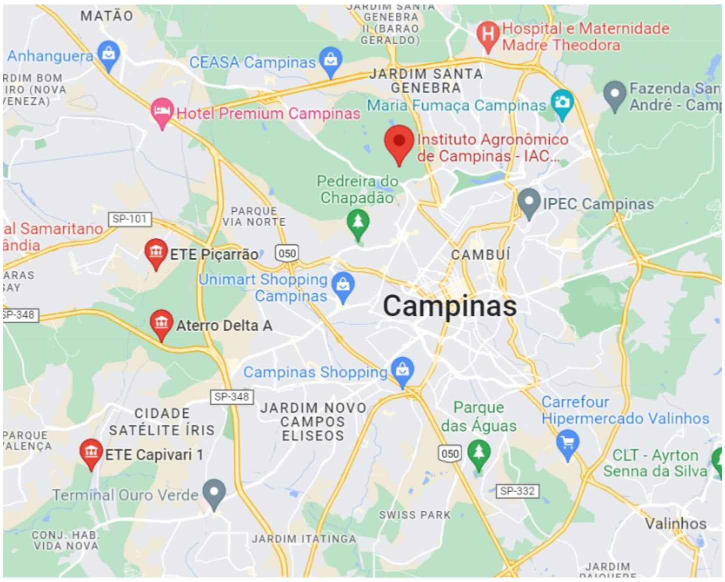

Figure 1: SANASA ETEs, Delta A landfill and IAC (Compost Project) locations.

The total volume to be processed daily by the Compost Plant is 100 tons/day of organic residues being 45 tons/day of green municipal residues[8] and 33 tons/day of dehydrated sewage mud[9] from SANASA sewage treatment plants (ETE) and 22 tons/day of residues from fruits and vegetables residues[10] from CEASA wholesale market. Presently, the Compost Plant is only using the green material and the sewage mud.

The related monitoring services includes: a) Engineering to monitor biological composting process, b) Laboratory analysis of composting material (including relation C/N), c) Laboratory analysis of underground waters (including DD 256/14 CETESB), d) Loading and transporting of bio-cake, as well as the wood chips and material rejected from screening cycle, until 25 km (IAC, Delta A, IAC), e) Loading and transporting percolating liquids from composting plant to the SANASA´s sewage treatment plants.

The green residues are weighted at the Delta A Sanitation Landfill or at the Compost Plant. Then, they are unloaded at the Compost Plant where they are

[8] Branches, trunks, and roots
[9] 75% solid content
[10] 60% moisture content

segregated to remove the inert material. Then, the material is grinded, homogenized in piles, then goes to an anaerobic composting process (windrows) and through screening the compost. Last, the material is let to mature in open field and eventually stays in "buffer areas" before being transported.

The SANASA sewage treatment plants (ETE) dehydrated mud is initially sent to the Delta A Sanitation Landfill to be weighted. Then this material receives dolomitic limestone and wood chips in different proportions and pre-determined by the contractor. At this step, the mix or homogenized material becomes the "bio bake" constituted by the SANASA mud, dolomitic limestone, and woody fractions. This material will constitute the windrows to be submitted to the removal of the inert and hazardous material.

The anaerobic composting process is composed of organic material bio-oxidation exothermic reactions with the objective to eliminate pathogenic organisms present in the residues, therefore eliminating risks to environment and public health.

The composting process is composed in four steps:

- the organic matter presents ambient temperature (20-25°C), cryophilic phase,
- the temperature slowly rises from 25 to 55°C, mesophilic phase,
- the temperature reaches 55°C, thermophilic phase,
- the temperature reaches 65°C, maturity phase, in which the organic matter biologically stabilizes and slowly cools down to ambient temperature.

The Compost Plant was installed in an area of 67 thousand m^2, being 44 thousand m^2 to receive the material and house the windrows and 23 thousand m^2 for temporary stocking or maturing of compost material.

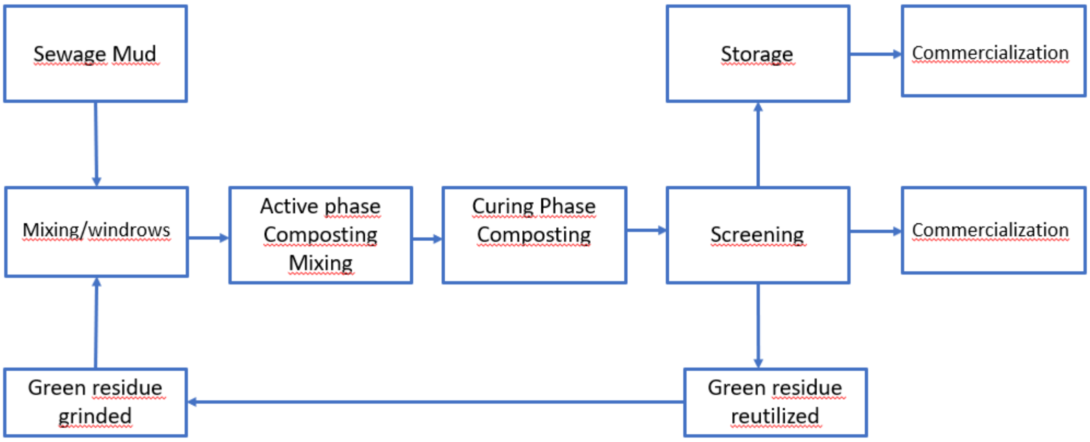

Figure 2: Schematic composting process flow of the Compost Plant.

4. Compost Plant Operating System

The Compost Plant is composed of the following steps:

a. Grinding operation

The municipal green residues are received at the Compost Plant, and preliminarily will pass by a primary segregation. This comprehends separation of materials that can´t be decomposed, and removal of visible impurities, considered inert material. In the sequence a tractor discharges the residues and completes the separation to prepare the material to be grinded. Then, the grinding process of trunks and branches begins, and two piles are created, one for the wood chips and the other for the dehydrated sewage mud. These materials will then be mixed in order to form a homogeneous mixture to allow the composting process.


Figure 3: Green urban residues received at the Compost Plant.

The grinding is performed until wood chips maximum of 150 mm size are obtained, so to allow air circulation inside the pile. The material needs to be well mixed with the objective to maintain an equal C/N ratio and increase the contact between the particles for the beginning of the composting process. The grinded material will be mixed with the dehydrated sewage mud. The wood grinder is a "HAAS / BRUNO INDUSTRIAL", model TYRON 2000 XL, low rotation with two axes, self-propelled with tracks. Its main features: power 400 HP, width between axes: 2,000mm, axes diameter: 700mm, dimensions: L – 10.7 m; W – 2.55 m; H – 3.15 m, rotation until 41 rpm, and granulometry until 150 mm.

Figure 4: The HAAS / BRUNO INDUSTRIAL", model TYRON 2000 XL wood grinder.

The grinded material is then transported using wheel-loaders and trucks to make the windrows. The quantity handled daily is around 45 tons of green material and 33 tons of dehydrated sewage mud, totaling around 78 tons/day.

b. Forming and unforming of composting windrows

The composting windrows are made with the homogenized grinded material. The windrows are about 2-3m high and built with help of trucks and wheel-loaders. In the windrows the material starts the initial phases of anaerobic composting, passing by the phases of phytotoxicity, bio stabilization, and humidification. The final product (matured organic compost) will be analyzed to determine its N-P-K composition, moisture content, texture, and C/N ratio.

Figure 5: Compost windrows being aerated.

The Compost Project received a license emitted by CETESB, the São Paulo State company responsible by controlling, inspecting, monitoring, and licensing pollution-related activities. This license determines the compost quality certification. The compost registration is presently in process at the Brazilian Ministry of Agriculture (MAPA) as "organic fertilizer compost or B class soil conditioner" according to the legislation applied to the use of organic compost in agriculture. During the anaerobic composting several parameters should be monitored, such as moisture, curing time, color, and specially the organic matter temperature. Initially the windrow should be around ambient temperature, increasing during the other phases (mesophilic and thermophilic) reaching between 45 to 65°C. The homogeneous composting material is then transported by 12m^3 trucks to the next process step, which involves screening. All segregated material is transferred back to the Delta-A Landfill.

c. Aeration process of windrows

The next step in the composting process involves the aeration of composting windrows. This aeration process uses a windrow revolving mixer which supplies oxygen to the organic matter creating adequate conditions for aerobic decomposition. This aeration process allows the organic matter to fully stabilize. This windrow turner supplied by MENART, model SPM-55, is self-propelled, with tires, and capacity to handle a minimum of 4,000 tons/hour, with a minimum tunnel height of 2.0 m and minimum tunnel width of 4.5 m. The equipment has automatic lubrication and forward speed of 1,200 m/hour. The daily quantity of material to be handled in the Compost Project first phase is around 80-100tons.

Figure 6: The Compost Plant aerial view.

Besides aeration, there is a need for a daily and systematic humidification. Tank truck of 10m^3 sprays water over the compost windrows to maintain the moisture. For the windrows, the humidification process is necessary to optimize the biological processes.

Figure 7: the compost windrows being humidified.

d. Screening operation of compost material

During the maturity step, the composting windrows are systematically aerated by the mixer device (windrow turner shown in the above picture) with the objective of creating the favorable aerobic conditions. The maturity step lasts about 30-45 days. The figure below shows the compost material in the windrows.

The next step in generating a homogenous compost is the screening process in which are separated particles based on granulometry. The objective of this segregation is to eliminate larger fractions that could disturb the manipulation of organic material in its application. These larger fractions are recycled back in the beginning of process (grinding step) with the objective to activate the biological conditions, considering the material rich microorganism content. After the screening process is completed, the material will rest to gradually lose its heat until reaching ambient temperature. This thermal equilibrium is an indication that the organic compost will not cause any harm to its recipient, and the compost is then ready to be used/commercialized. The screen has a fast-replacing drums to handle materials with higher moisture content. This equipment is supplied by Bruno Industrial, model RODO PRB-06, with the following features: drum diameter 2,000 mm, length 6,000 mm, production capacity until 130m³/hour, rotary brush for cleaning.

Figure 8: The compost screening operation.

e. Charging and transporting the bio cake

The dehydrated sewage mud produced by the SANASA sewage treatment plants of Capivari and Piçarrão are produced in UASB reactors. Before its transportation by SANASA, the mud is dehydrated by centrifuges and mixed with limestone and woody residues. This mixture, named now "bio cake", is then transported to the Compost Plant. The average distances from the SANASA sewage treatment plants to the landfill and the Compost Plant is 25 km.

5. Laboratorial analysis and monitoring

a. Monitoring Carbon/Nitrogen ratio

The biological composting process technical control indicates the organic matter decomposition (temperature and C/N ratio) defining the time for each process phase. At the moment, because only the green residues and sewage mud are used, there is a high carbon content in the compost. The C/N ratio is the most important parameter related to the organic matter decomposition by microorganisms. The monitoring of this parameter allows the better understanding of the entire composting process. Two samples are analyzed monthly to verify its C/N ratio.

There is also the underground water analysis which consists of collecting and analyzing underground water in the project area. Presently, the windrows site is dry (no slurry is produced). There are 4 sampling wells in the project area. The samples are taken every three months performing 16 samples per year. The objective here is to identify any pollution contaminating the underground aquifer.

The parameters follow CETESB recommendation (Directory Directive n° 256/2016/E): bicarbonate alkalinity, carbonate alkalinity, hydroxide alkalinity, aluminum, antimony, arsenic, barium, cadmium, calcium, lead, cyanite, chloride, cobalt, copper, conductivity, color (true), chromium, total hexavalent, DBO, COD, water hardness, phenol, iron, fluoride, total phosphate, magnesium, manganese, mercury, molybdenum, nickel, nitrogen, ammonia, nitrogen nitrate, nitrogen nitrite, nitrogen albuminoids, consumed oxygen, potassium, silver, total solids, selenium, sulphate, turbidity, zinc, Total Organic Carbon (TOC), total coliforms, fecal coliforms, Bacteria Standard Counting, pH, and temperature.

b. Final compost quality control and composition

Mud quality control: The sewage mud to be used as raw material for compositing, will be analyzed monthly. The analyzed parameters are agronomic and heavy metals.

Agronomic parameters: pH, density, moisture(65°C), organic matter, organic carbon, nitrogen, phosphor, potassium, calcium, magnesium, sulfur, C/N ratio, manganese, boron, and sodium. Heavy metals: arsenic, barium, cadmium, lead, coper, total chrome, chrome+6, mercury, molybdenum, nickel, selenium, zinc

Compost quality control: Each compost batch characterized either as organic fertilizer or soil conditioner, is analyzed in relation to its agronomic parameters, Water Retention Capacity (WRC)%, Cationic Change Capacity (CCC), ratio CCC/C.org and C/N ratio

Agronomic parameters and heavy metals the same as described in mud quality control. Inert materials: glass, metals, and stones. Pathogenic microorganisms: thermos-tolerant coliforms, helminth, and salmonella viable eggs.

A typical compost analysis can be found in Table 1, below.

Table 1: Typical Compost analysis produced by the Campinas Compost Plant.

Parameter	Method	Unit	Result
Arsenic	(a)	mg/kg	< 1.0[2]
Barium	(a)	mg/kg	1.2
Mercury	(a)	mg/kg	< 1.0[2]
Ammoniacal Nitrogen	(b)	mg/kg	126

Inorganic Nitrogen (nitrate+nitrite)	(b)	mg/kg	17.9
Kjeldahl Nitrogen	(b)	g/kg	9.7
Organic Carbon	(b)	g/kg	269
pH (1:10)	(b)	---	8.7
pH in $CaCl_2$	(c)	---	7.8
Potassium	(a)	mg/kg	4452
Selenium	(a)	mg/kg	< 1.0[2]
Sodium	(a)	mg/kg	1753
Total Solids	(b)	%(m/m)	30.5
Volatile Solids	(b)	%(m/m)	36.7
Moisture Content	(b)	%(m/m)	69.5

(a) Metals: EPA-SW-846-3051, with determination by ICP-AES, according to EPA-SW-846-6010 and potassium and sodium by flame photometry; (b) Total nitrogen: Kjeldahl method; ammoniacal nitrogen, nitrate and nitrite: distillation by vapor drafting; Moisture and Volatile solids: mass loss at 60 and 500°C, respectively; pH, determination in aqueous extract in proportion 1:10 (residue:water), according to methods described by "de Andrade, J.C.; de Abreu, M.F. (eds), Análise Química de Resíduos Sólidos para Monitoramento e Estudos Agroambientais, Editora IAC, Campinas, 2006, 178p.";(c) Manual de métodos analíticos para fertilizantes e corretivos (Brasil, 2017).

1. all results are expressed in dry basis; 2. not quantified, less than the quantifying limit

6. Compost Project economic assessment

Naturally, the most important impact of this project is the elimination or reduction of pollutant agents, such as the sewage muds and green urban residues. Important direct investments were made by the City of Campinas and the SANASA water and sewage company. Basically, the project costs are related to fixed costs such as the acquisition of necessary machinery (grinder, compost mixer, screener, and other auxiliary equipment such as the humidification truck, wheel-loaders, trucks) and variable costs for the acquisition of diesel, and labor. The present equipment shown in the above picture are oversized and can handle larger volumes. Therefore, it is not recommended to use them to conduct a project cost/benefit analysis.

Regarding the benefits, they can be divided as: a) an avoided cost of sparing the city landfills, b) the future commercialization of the compost as organic fertilizer or soil conditioner; and c) the future commercialization of carbon credits derived from the organic material recycling and fossil fertilizer mitigation. It has been estimated that the avoided costs of disposing the green urban residues and sewage mud are in the order of US$ 200,000/month. The other benefits have not yet been calculated.

Presently, the compost is utilized inside the public administration. After the Compost Project receives the registration by the Brazilian Ministry of Agriculture, the compost will be sold to another company for commercialization.

7. Conclusions

The objective of this article is to present the Compost Project (Usina Verde) organized between the Agronomic Institute of Campinas – IAC, the City of Campinas, the SANASA Water and Sewage Company of Campinas and CEASA Campinas. This project was a result of the Agropolo Campinas-Brasil cooperative platform to increase the value of agriculture and rural residues and improve the environment conditions in the metropolitan region of Campinas.

Another impact of this project is to generate a compost that can be used as fertilizer substitute among the rural producers in the region. Fertilizer is becoming more expensive and a great concern among producers in Brazil.

Now, the idea is to replicate this experience in other cities in Brazil. The country has around 6,000 cities and a powerful agribusiness sector very interested to adopt sustainable solutions.

Acknowledgements

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