S&G 16 (2021), pp. 308-319

S&G Journal

REVISTA S&G
ISSN: 1980-5160

PÓS-GRADUAÇÃO DINÂMICA DOS OCEANOS E DA TERRA UFF

REGIONAL ENVIRONMENTAL IMPACTS FROM CHANGING ENVIRONMENTAL LEGISLATION FOR CO-PROCESSING OF AGROCHEMICALS

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ABSTRACT

The enactment of the new CONAMA Resolution No. 499/2020 now authorizes the co-processing of agrochemical packaging and post-consumption leftovers, which were previously prohibited. Due to this issue, the reverse logistics of these packages, consolidated in Brazil for almost two decades, will suffer serious threats. The general objective of this work is to investigate the potential environmental impacts generated by the recent regulation, identifying the states, immediate and intermediate regions and municipalities that will be most affected by these legal changes. For this, a comparison of the impacts between the Campo Limpo System and co-processing was made through Life Cycle Assessment, considering as a functional unit the final destination of 45 thousand tons of packages and 100 tons of leftovers in a period of one year, using the ReCiPe method. The results proved that the potential impacts are lower by 12% in the climate change category, 7% in marine ecotoxicity, 2% in water ecotoxicity, and 1% for particulate matter formation, photochemical oxidant formation, and human toxicity in the Campo Limpo system. We conclude that the new CONAMA resolution will encourage environmental setbacks and will not contribute to the mitigation of any impact on disposal. The Metropolitan Mesoregion of Belo Horizonte and the municipality of Cantagalo-RJ will be the places that will suffer most from these impacts because they have the highest concentration of clinker ovens for co-processing in the national territory. The continuity of the Campo Limpo program is recommended as the best option for final disposal of this high environmental risk waste.

Keywords: Co-processing; Pesticides; Packaging; Reverse Logistics; Environmental Impacts.

PROPPI / DOT
DOI: 10.20985/1980-5160.2021.v16n3.1743

1. INTRODUCTION

With the enactment of Federal Law No. 12,305 of 2010 (Brazil, 2010), which addresses the National Policy for Solid Waste in Brazil, several industry sectors, such as tires, batteries, and electro-electronics, have sought to advance in the implementation of reverse logistics of their waste based on industry agreements, but not as successfully as the sector of pesticide packaging and its waste, which, by force of Law No. 7,802 of July 11, 1989, subsequently amended by Law No. 9,974 of June 6, 2000 and Decree No. 4,074 of January 4, 2002 (MMA, 2014), had already implemented a system.

As of the year 2002, the National Institute for Empty Packaging Processing (INPEV, 2019a) was created and began operating this collection and reprocessing system, called Campo Limpo (CL). After almost two decades, the CL system has become a world reference, reaching 94% recycling of these packages throughout Brazil (INPEV, 2020).

The CL system as a whole is composed of the following stages: washing, storage, electronic scheduling, receiving units, and final destination. The structure of the system has 411 stations and receiving centers throughout Brazil (INPEV, 2020).

Since the beginning of the program, approximately 1.4 billion has been invested by the pesticide sector that makes up INPEV to fund the activities of all links in the chain, with the collection of 550,000 tons of pesticides, with 45,000 tons in 2019. In 2018, 100 tons of post-consumption pesticide waste was also collected. The leftovers, which are delivered to the system's receiving units, are properly packaged in barrels and follow the same destination as unwashed packaging, incineration (INPEV, 2019ª).

In addition to reverse logistics, the CL system also enables the circular economy, manufacturing new packages from post-consumption resin, supplying the sector itself. In addition, this resin is also used in the manufacture of other materials, such as artifacts for the construction industry, transportation and energy, generating savings of natural resources and avoiding the emission of 752,658 tons of CO_2 in the period between 2002 and 2019 (INPEV, 2019a).

However, the enactment of the new CONAMA Resolution No. 499 of October 6, 2020 (CONAMA, 2020), which revoked Resolution No. 264 of August 6, 1999 (CONAMA, 2000), provides for the licensing of waste co-processing (CP) activities in rotary kilns for clinker production, and threatens the environmental gains achieved over the years by the implementation of the CL system, since the old resolution vetoed the CP of pesticides and toxic waste.

The CP technique has been employed worldwide in order to reduce fossil fuel and raw material consumption in cement manufacturing, which has enabled the reduction of CO_2 emissions. This involves the use of, for example, rejected tires from industrial activities, oils and grease, solvents, paint residues, other residues with combustible characteristics, and even urban solid residues, as alternative fuels and raw materials (Lamas *et al.*, 2013, p. 201; Dias *et al*. 1999, p. 155).

In the scope of this new resolution, in the sole paragraph of Article 2, it is mentioned that the environmental agency may authorize the CP of residues with concentrations of organic pollutants higher than those established by the resolution itself, as long as environmental gains are proven, such as:

> I - reduction in the emission of pollutants, greenhouse gases, among others; II - elimination or reduction of the need for final disposal of waste; III - depollution of areas or water courses; IV - the CP is presented as an environmentally more appropriate and safe technology for the final disposal of waste, among others (CONAMA, 2020).
>
> Annex I of the mentioned resolution presents a list of Persistent Organic Pollutants (POP) that may be co-processed (CONAMA, 2020).

POPs have different synthetic organic physical and chemical characteristics such as semi-volativeness, persistence, bioaccumulation, and toxicity. These compounds are present in agrochemicals (CETESB, 2020a).

It is worth mentioning that the cement production activity has many impacts, such as contributing to the scarcity of abiotic resources from the mineral extraction of gypsum and other components, as well as the consumption of fossil fuel sources, necessary in the production of clinker, which leads to atmospheric emissions that contribute to climate change.

The use of cement kilns for CP requires secondary facilities for waste storage and handling that ensure safety for both workers and the environment, such as a hazardous waste processing plant (Dias *et al.*, 1999). The study conducted by Aguiar et al., (2020) reports the potential impacts on health and the environment of the preparation of more than one hundred and seventy types of waste, from the most diverse sectors of national industry, in facilities known as *blendeiras* ("blenders"), located in Magé-RJ. In Brazil, there are nineteen blenders (Abetre, 2013). Pinto Jr. and Braga (2009) found a process of illness among cement factory workers who handled the waste before it was co-incinerated in cement kilns. They highlight symptoms such as discomfort to the unpleasant odor, headache, nausea, burning eyes, respi-

Revista S&G
Volume 16, Número 3, 2021, pp. 308-319
DOI: 10.20985/1980-5160.2021.v16n3.1743

ratory problems, skin contamination, itching, dizziness, and fainting.

It is understood that regional development plans, projects, and policies must take into consideration several sustainability criteria. Among them is the promotion and use of environmental management of hazardous substances and waste (MMA, 2002). Therefore, the justifications employed by the aforementioned CONAMA resolution are extremely fragile and should be subject to analysis with regard to the consequences to the environment, with social and economic developments that this new framework can bring to the Brazilian regions.

“The general objective of this work is to compare the potential environmental impacts generated in the disposal of agrochemical packaging and leftovers by the traditional Campo Limpo system with the co-processing proposed by the recent regulation of the new CONAMA resolution, identifying the states, the immediate and intermediate regions, and the municipalities that will be most affected by these legal changes.

Geographical contexts of CL and CP systems”.

The final disposal units of the CL system are fourteen in total, specifically ten recycling plants and four incinerators. These plants are located in three regions of Brazil: Southeast, South, and Midwest (**Table 1**).

The state of São Paulo is home to the most units, seven recyclers and two incinerators (INPEV, 2019b). The immediate regions of São Paulo, represented by the municipalities of Guarulhos, Taboão da Serra and Suzano and that of Taubaté-Pindamonhangaba, are those that concentrate a greater number of disposal units, three each.

The cement plants with rotary kilns licensed for PC in Brazil are thirty-eight and belong to nine business groups. These cement plants are located in thirty-six municipalities, 45% of which are located in the Southeast Region (**Table 2**). The municipality with the largest number of plants is Cantagalo-RJ, which has a cement hub, with three plants (ABCP, 2020), within a radius of only 5km.

The State of Minas Gerais has the largest concentration of cement plants with kilns for co-processing in Brazil, with eight units located within a radius of approximately 200 km, only in the Metropolitan Mesoregion of Belo Horizonte (*Mesorregião Metropolitana de Belo Horizonte* - MMBH). The non-metallic minerals sector, where the cement sector is included, is considered one of the most developed economic activities in this region (AMM, 2014).

Figure 1 shows the geographical distribution of the PC units and also of the recyclers and incinerators of the CL system throughout the country.

Table 1. Final disposal units of the CL system

N	Location	Country Region	Unit	%
1	Guarulhos (SP)	Southeast	Vasitex Vasilhames LTDA.	79%
2	Taboão da Serra (SP)		Essencis Soluções Ambientais S.A.*	
3	Suzano (SP)		Clariant S.A./PCN Suzano SPE S.A.*	
4	Taubaté (SP)		Campo Limpo Tampas e Resinas plásticas LTDA.	
5	Taubaté (SP)		Campo Limpo Reciclagem e Transformação de plásticos LTDA.	
6	Pindamonhangaba (SP)		Eco Paper Produtos em Papel LTDA.	
7	Tietê (SP)		Tubolix Embalagens LTDA.	
8	Piracicaba (SP)		Global Steel Transporte e Comércio de Ferro e Aço EIRELI	
9	Louveira (SP)		Dinoplast Indústria e Comércio de Plásticos LTDA.	
10	Sarzedo (MG)		Ecovital Central de Gerenciamento Ambiental S.A.	
11	Uberaba (MG)		Neotech Soluções Ambientais LTDA.*	
12	Cuiabá (MT)	Midwest	Plastibrás Indústria e Comércio LTDA.	7%
13	Tangará (SC)	South	Valpasa Indústria de Papel LTDA.	14%
14	Maringá (PR)		Neotech Soluções Ambientais LTDA.*	

Source: INPEV 2019b (*) Incinerators

Table 2. CP Plants in Brazil

N	Localition	Country Region	Group	%
	Cachoeiro de Itapemirim (ES)	Southeast	Nassau	45%
	Arcos (MG)		CRH	
	Barroso (MG)		Holcim	
	Carandaí (MG)		Tupi	
	Ijaci (MG)		Intercement	
	Itaú de Minas (MG)		Votorantim	
	Montes Claros (MG)		Holcim	
	Matozinhos (MG)		CRH	
	Pedro Leopoldo (MG)		Holcim	
	Pedro Leopoldo (MG)		Intercement	
	Vespasiano (MG)		Liz	
	Cantagalo (RJ)		CRH	
	Cantagalo (RJ)		Holcim	
	Cantagalo (RJ)		Votorantim	
	Apiaí (SP)		Intercement	
	Cajati (SP)		Intercement	
	Salto Pirapora (SP)		Votorantim	
	São Miguel Campos (AL)	Northeast	Intercement	21%
	Campo Formoso (BA)		Intercement	
	Quixerê (CE)		Apodi	
	Sobral (CE)		Votorantim	
	Caaporã (PB)		Holcim	
	João Pessoa (PB)		Intercement	
	Goiana (PE)		Nassau	
	Laranjeiras (SE)		Votorantim	
	Sobradinho (DF)	Midwest	Votorantim	16%
	Cezarina (GO)		Intercement	
	Bodoquena (MS)		Intercement	
	Itaú de Corumbá (MS)		Votorantim	
	Nobres (MT)		Votorantim	
	Cuiabá (MT)		Votorantim	
	Rio Branco do Sul (PR)	South	Votorantim	10%
	Balsa Nova (PR)		Itambé	
	Candiota (RS)		Intercement	
	Pinheiro Machado (RS)		Votorantim	
	Manaus (AM)	North	Nassau	8%
	Capanema (PA)		Nassau	
	Xambioá (TO)		Votorantim	

Source: ABCP, 2020

Revista S&G
Volume 16, Número 3, 2021, pp. 308-319
DOI: 10.20985/1980-5160.2021.v16n3.1743

2. MATERIALS AND METHODS

In this study, the method that will be used for comparison between the two systems is the Life Cycle Assessment (LCA). This method has as its main references the technical standards NBR ISO 14040:2006 and 14044:2009 (ABNT 2009). This methodology is divided into four steps: definition of objective and scope, Life Cycle Inventory (LCI) analysis, Life Cycle Impact Assessment (LCIA), and interpretation, which in this study will be replaced by the conclusions section.

Scope

The scope of this study covers a comparison between the disposal process of the CL system and the PC system.

The functional unit for this comparison will be the treatment of 45,000 tons of packaging and 100 tons of post-consumer pesticide waste destined in one year. These figures are based on the CL system's disposal data in 2019.

For the purposes of delimiting the system boundary, only the final disposal stage was considered using the "gate-to-grave" approach. This study did not compute the impact of waste generation, transportation, waste storage in previous stages, or the new life cycle of packaging arising from recycling in the specific case of CL.

The substance high density polyethylene (HDPE) was chosen for pesticide containers, which represent the largest quantity among the types of packaging. Glyphosate, the most widely used pesticide in Brazil, was chosen for the pesticide leftovers.

In the CL product system, the percentage of recycled packages is 94% of the total packages collected, and the rest (6%) is incinerated along with the leftover pesticides (INPEV, 2019b). As for the PC product system, the disposal of 100% of these same wastes in the cement kiln was considered. In the PC, natural resources for the manufacture of cement and other co-processed waste were not considered, i.e., only packaging and leftovers were considered. The percentage of 5% was used as a mass cutoff criterion, i.e., any mass entering the process that corresponds to less than 5% of the total mass of the product was eliminated. Figure 2 shows a schematic representation of the system boundaries.

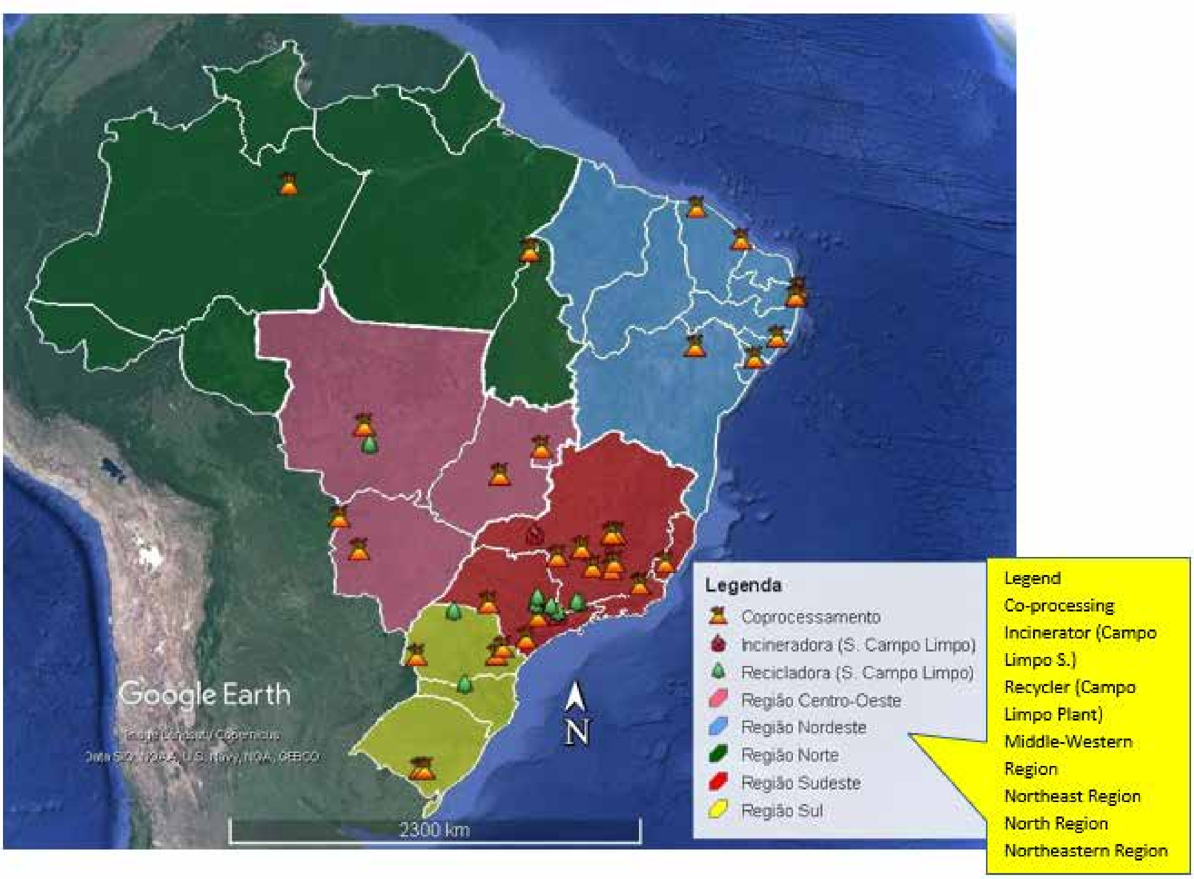

Figure 1. Geographical distribution of CP and CL

Sources: INPEV 2019b; ABCP 2020 (adapted)

The chosen LCIA method was ReCiPe V.1.04 Midpoint (H), which considers a balance of effects between the short and long term (Rocha, 2017). The normalization set was ReCiPe World H. The ReCiPe method is recommended for LCIA in Brazil (Mendes et al., 2016, p. 165; IBICT, 2019), as they present the impacts characterization factors, created by Huijbregtset et al. (2016) for the categories Photochemical Oxidant Formation (POF), Particulate Matter Formation (PMF), Terrestrial Acidification (TA), Freshwater Eutrophication (FE), and Water Depletion (WD), specific for the country.

Life Cycle Inventory (LCI)

From the data collected based on the balance of the year 2019 of the CL system (INPEV 2019b), the LCI was obtained based on the elementary flows coming from or going to the environment (resources, emissions, effluents, and depositions) with the aid of the SimaPro Data Server software (2006) with ecoinvent, resulting in many flows in the inventory, which were subsequently reduced by the cut-off criteria.

Life Cycle Impact Assessment (LCIA)

SimaPro v.7.2 (2010) software was used to study the environmental impact categories. All categories of the ReCiPe method were adopted, aiming for a broad investigation of the impacts. Table 3 provides a brief definition of the impact categories.

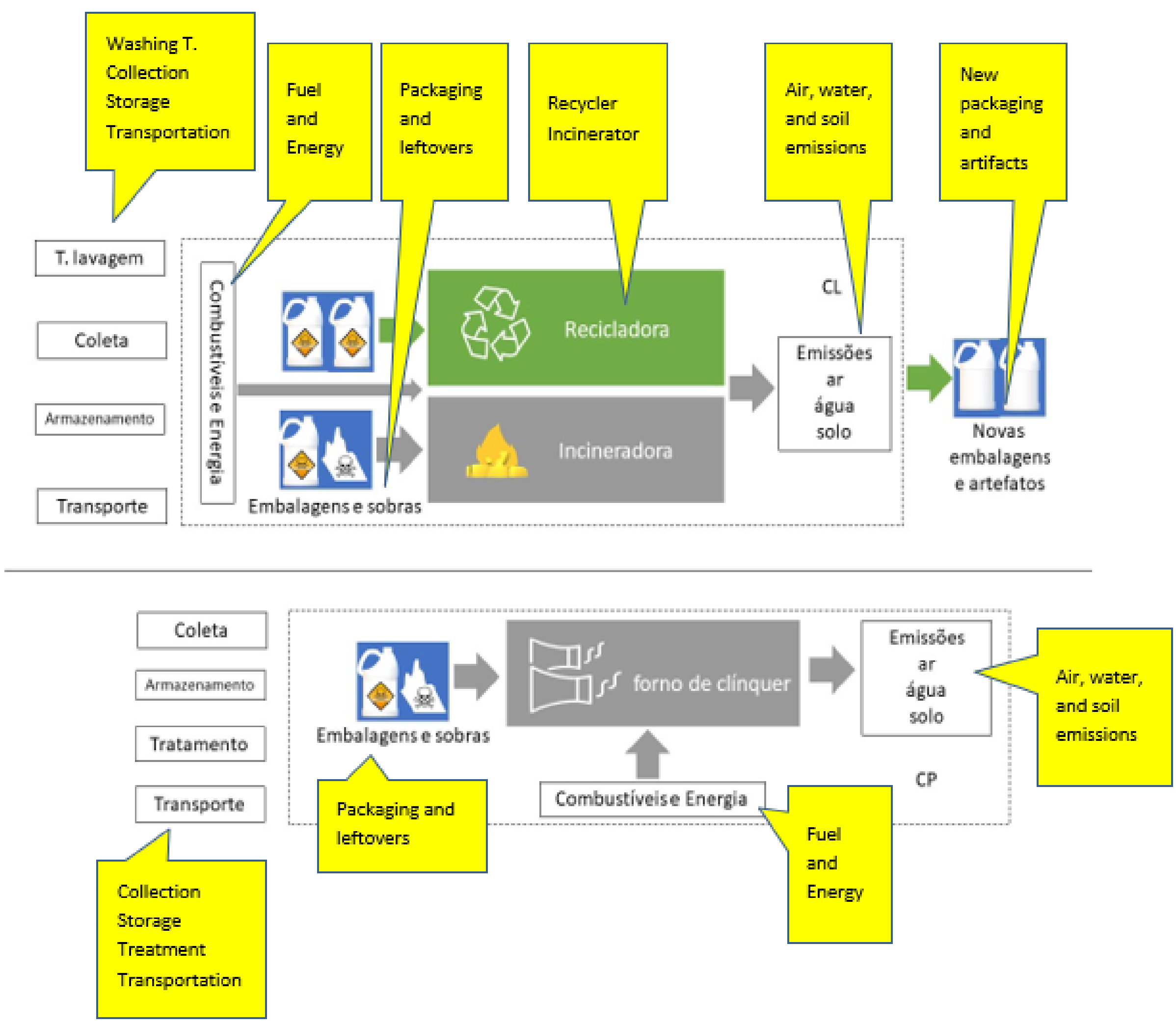

Figure 2. Delimiting the boundaries of the LC and CP systems

Source: own elaboration

Revista S&G
Volume 16, Número 3, 2021, pp. 308-319
DOI: 10.20985/1980-5160.2021.v16n3.1743

Table 3. Impact categories used in the article

Impact Category/ Acronym	Effect
Climate Change (CC)	It results in adverse effects on biomes, ecosystems, cities, and human health. This impact is related to greenhouse gas emissions into the atmosphere. The unit is kg CO_2 eq.
Ozone Depletion (OD)	It explains the destruction of the ozone layer by destructive substances such as chlorofluorocarbons (CF). The unit is kg CFC-11 eq.
Terrestrial Acidification (TA)	Increase in the acidity content of the soil caused by the disposal of acid tailings, such as the emission of nitrogen oxides (NOx) and sulfur oxides (SOx), which combine with water in the atmosphere, precipitating as acid rain and consequently causing effects on fauna and flora. The unit is kg SO_2 eq.
Freshwater Eutrophication (FE)	It results from increased concentrations of nutrients in the water or soil (phosphorus) caused by the disposal of tailings and consequently a potential increase in the number of species in the ecosystem. The unit is kg P eq.
Marine Eutrophication (ME)	Leaching of nutrients discharged into rivers or marine systems and the increase in nutrients. Nitrogen is assumed to be the limiting nutrient in waters. The unit is kg N eq.
Fossil Depletion (FD)	Decrease in the amount of fossil fuels by extraction and consumption. The unit is kg oil eq.
Water Depletion (WD)	Increased water consumption, affecting demand and availability. The unit is the m^3eq.
Metal depletion (MD)	The extraction of minerals and ores for various uses by humans. The unit is kg Fe eq.
Agricultural Land Occupation (ALO)	The amount of agricultural land occupied for a certain time. The unit is m^2 per year (m^2a).
Urban Land Occupation (ULO)	Ditto on urban land.
Natural Land Transformation (NLT)	The amount of natural land transformed and occupied for certain time. The unit is the m^2.
Water Ecotoxicity (WEC)	Results from the concentration of increased toxic agents caused by increased disposal of tailings, consequently causing potential damage to the hydrosphere. The unit is the kg 1.4 DB eq.
Marine Ecotoxicity (MET)	Ditto on the marine biome.
Terrestrial Ecotoxicity (TET)	Ditto on the lithosphere.
Human Toxicity (HT)	Ditto on human health.
Ionizing Radiation (IR)	Nuclear radiation contamination and consequent health effects. The unit is U235 eq.
Particulate Matter Formation (PMF)	Particulates and compounds generated in the combustion process, which can be retained in the upper part of the respiratory system, and can reach the lung alveoli, especially the smaller particles. The unit is the PM2.5 eq.
Photochemical Oxidant Formation (POF)	Negative impacts generated by photochemically generated pollutants (tropospheric ozone) due to its reactive nature that allows it to oxidize organic molecules, generating impacts to the human respiratory system and damage to vegetation. The unit is kg NOx eq.

Source: IBICT 2019; Rocha 2017; Huijbregts et al., 2016; Silva and Oliveira 2014; JRC-IES 2010.

In order to reduce uncertainties, the LCIA was limited to characterization only, i.e., the contribution of each impact stipulated through the flows of raw materials and emissions that are estimated using the characterization factors (H) of the ReCiPe method - 2016 (Huijbregts *et al.*, 2016).

The interpretation of the results of the LCIA sought to correlate the impacts found in the comparative with the environmental prognosis of the regions and municipalities that will suffer the greatest environmental pressures as a result of the change in legislation.

Although the methods classify the impacts by the spatial criterion, in this work, it was considered that the mechanisms of global impacts, such as Climate Change and the Depletion of the Ozone Layer, will bring possible consequences at the regional and local scale, both in the natural environment and in human health (JRC-IES 2010).

3. RESULTS AND DISCUSSION

Life Cycle Inventory (LCI)

Table 4 shows the LCI containing the main input and output flows of the final disposal systems of the studied systems.

Table 4. LCI for the final destination of 45 thousand tons of packages

	Substance	Compartment	Unit	CL	CP
ENTRADAS	Occupation, forest, intensive, normal	Raw Material	m^2a	0.5007771	0.5008944
	Occupation, forest, intensive, short cycle		cm^2a	303.13221	303.13274
	Occupation, industrial area		cm^2a	400.18	400.60
	Occupation, construction area		cm^2a	249.01522	249.14358
	Occupation, dumping site		cm^2a	271.50919	272.10811
	Occupation, mineral extraction area		m^2a	0.12432259	0.12433244
	Forest transformation		cm^2	121.12	121.17
	Sea and ocean transformation		cm^2	12.772997	12.780767
	Transformation to forest		cm^2	56.73	56.76
	Mineral coal		kg	8.28	8.28
	Natural Gas		m^3	4.0843801	4.0867965
	Crude Oil		kg	1.8015561	1.8028133
	Manganese		g	1.287808	1.2881352
	Copper		g	11.82	11.82
	Nickel		g	23.904071	23.925301
	Iron		g	193.08584	193.9162
	Chrome		g	9.9129901	9.9197817
	Freshwater		dm^3	208.85	209.9
SAÍDAS	Nitrate	Water	g	13.889529	13.951891
	Ammonium, ion		g	6.4990996	6.4991735
	Phosphate		g	42.978332	42.988935
	Phosphorus		g	24.002934	24.002937
	Manganese		g	11.184724	11.21228
	Nickel, ion		g	1.1988614	1.2002209
	Vanadium, ion		mg	135.01133	491.56714
	Chloroacetic acid	Air	g	2.7363736	2.7363736
	Nitrogen oxides		g	38.791303	39.156762
	Particulates, < 2.5 um		g	6.3874731	6.3959776
	Particulates, > 2.5 um and < 10um		g	5.9916847	5.9958587
	Sulfur dioxide		g	55.84447	55.863317
	Bromochlorodifluoromethane		µg	159.73645	159.85249
	Bromotrifluoromethane		µg	57.188847	57.241617
	Tetrachloromethane (CFC-10)		mg	6.5784934	6.578619
	NMVOCS		g	5.8128675	5.8775323
	Carbon dioxide, fossil		kg	20.756207	23.567109
	Carbon-14		Bq	377.1928	377.26506
	Radon-222		kBq	6.76E+03	6.76E+03
	Methane, fossil		g	54.541699	54.572852
	Mercury		mg	3.9671912	3.9692094
	Phosphorus		mg	942.14011	942.14044

Source: own elaboration

Revista S&G
Volume 16, Número 3, 2021, pp. 308-319
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Lifecycle Environmental Impact Assessment (LCIA)

After submitting the inventory data to characterization, the results indicated that the CP of agrochemical packaging and leftovers presented increased impacts in the categories: CC, MET, WEC, HT, POF, PMF and WD. The results of the characterization can be seen in **Table 5**.

Table 5. Characterization of environmental impacts

Impact category	Unit	CL	CP
CC	kg CO_2eq.	22.37	25.19
MET	kg 1.4-DB eq.	0.43	0.46
WEC	kg 1.4-DB eq.	2.88	2.92
HT	kg 1.4-DB eq.	32.36	32.65
POF	kg NOxeq.	0.0323	0.0326
PMF	kg PM2.5 eq.	1.17E-02	1.18E-02
WD	m^3	7.80E-09	7.83E-09
FD	kg oileq.	8.517	8.522
IR	kg U235 eq.	11.65	11.66
TA	kg SO_2eq.	0.0816	0.0817
FE	kg P eq.	4.62E-02	4.62E-02
ME	kg N eq.	0.0236	0.0238
TET	kg 1.4-DB eq.	0.0577	0.0577
OD	kg CFC-11 eq.	6.64E-06	6.64E-06
ALO	m^2a	0.539	0.539
ULO	m^2a	0.263	0.263
NLT	m^2	0.0054	0.0054
MD	kg Fe eq.	1.65	1.65

Source: own elaboration

Thus, the consequences of the impacts brought about by the change in the criteria for licensing CP activities will be aggravated in the regions that host these activities and, by the geographical criteria presented in the section "Geographical contexts of the CL and CP systems", the MMBH stands out in the regional context and the municipality of Cantagalo-RJ in the local context.

In the CC category, the impact will be aggravated by 12% in the CP. The main substance contributing to the impact is fossil carbon dioxide emitted into the air from waste burning in kilns (Figure 3). Climate change causes extreme events such as flooding in urban areas and forest fires from drought, reduction and migration of biodiversity, and effects on human health such as thermal discomfort, stress, and infectious diseases (JRC-IES, 2010). Studies on climate change in MMBH point to the following sensitivities: poor road infrastructure conditions, population concentrated in urban areas, high urbanization (heat islands), relevant environmental risk, and risks of intense rainfall (FEAM, 2014).

As for impacts on ecosystems, there was a 7% and 2% growth by CP, in the MET and WEC impact categories, respectively (Figure 3). In both, the main substance responsible was phosphorus emitted into the water. In water, phosphorus reacts with oxygen and in an environment with little oxygen, can generate more toxic substances, such as phosphine (COFIC, 2020).

The worsening of the MET impact applies directly to the context of CPs situated in locations on the Brazilian coast, more specifically, the municipalities of João Pessoa (PB) and Laranjeiras (SE).

As for the impact of the WEC, this has a direct effect on the quality of the hydric resources in all locations. The largest concentration of CP furnaces in the state of Minas Gerais is overlapped with two national hydrographic regions, that of the São Francisco River and Paraná River, with emphasis on the Rio Grande (GD2) and Upper São Francisco River slope basins, with the Rio das Velhas as the main tributary, on the limits of the State Environmental Protection Area of Cachoeira das Andorinhas (CBHSF 2018; IGAM, 2020), sheltering springs that give rise to the water body with the same name, which is a water catchment and supply point for the Metropolitan Region of Belo Horizonte (ISA, 2010). In the municipality of Cantagalo, the most vulnerable basins are those of Negro River and Macuco River, where the cement industry is located.

The phosphorus emitted into the atmosphere, in turn, was the main substance responsible for HT, which showed a 1% increase in CP (Figure 3). Phosphorus is probably emitted first into the atmosphere after the CP of glyphosate and subsequently deposited in soil and water. Glyphosate is a compound from the group of organophosphorus pesticides, which are the most dangerous and toxic, although less persistent in soil (Matos, 2010). Chronic exposure to phosphorus, usually in the workplace, can lead to bone necrosis, spontaneous fractures, anemia, and weight loss (COFIC, 2020).

Photochemical Oxidant Formation and Particulate Matter Formation also had the CP increase by 1%. The main substance emitted was nitrogen oxide (NOx). NOx are irritating to the eyes and poisonous if inhaled (CETESB, 2020b).

The CP also proved to be more impactful at 0.5% in the WD category and 0.2% for FD (Figure 3). The higher water consumption in the CP may be linked to the wetting of roads for dust reduction and, especially, for the cooling system of the plant (Matos, 2010). Fossil depletion is due to the use of fossil sources such as petroleum coke, which are traditional fuels for cement kilns.

It is worth remembering that all the percentages of impact increase found are extremely relevant, even the smallest, since the CP already has great polluting potential (COPAM, 2017), as recorded in the "Scope" section, and will be further accentuated by the insertion of pesticide packaging and leftovers.

4. CONCLUSIONS

Considering the results obtained, one can conclude that the new scope of modifications contained in CONAMA's Resolution 499/2020 is harmful to sustainable development, with environmental setbacks also to the agricultural and cement sectors for several reasons. Firstly, because of the cement industry's greater contribution to the aggravation of climate change, due to the increase in CO_2 eq. emissions. This fact is a contradiction in the environmental guidelines of the sector that has sought to reduce greenhouse gas emissions (GHG).

On the spatial issue, the environmental impacts aggravated by the CP will lead to greater environmental pressures in all municipalities that have furnaces equipped for CP, with the exception of the MET impact, which applies only to the context of coastal municipalities.

The municipality of Cantagalo-RJ will suffer direct aggravation of environmental pressures, already existing by the CP with the entry of these new residues, because the Região Serrana fluminense is also an important agricultural sector of the state that may opt for the disposal of pesticides through the CP route. In addition to harm to the population's health by HT, the watersheds of Rio Negro and Macuco will be even more vulnerable to WEC and WD impacts.

Regionally, the MMBH stands out, and could be the region of the national territory that will most absorb the synergistic effects of the impacts on ecosystems, due to phenomena such as droughts and water shortages, which already affect the water resources of the Upper São Francisco Basin and part of the Paraná Basin. In addition, the WEC and WD impacts will have negative effects on the quality and availability of water resources.

It is worth pointing out that the mechanisms of these impacts will damage the health of the population residing in all locations, with increases in cases of infections, thermal discomfort, respiratory system diseases, culminating in hospitalizations and mortalities, with social and economic losses, especially to the public health system.

The cement plant workers are the most vulnerable class, as they are already subjected to various health risks from constant exposure to toxic substances from hundreds of types of co-processed hazardous waste, and in the future, also to pesticide residues.

It is worth pointing out the imminent possibility of destabilization of the reverse logistics of the CL system, which has, over the years, been making investments and presenting mitigation of environmental impacts that can be proven through sustainability reports of the program, originated from an extensive chain of reverse logistics and circular economy in the last twenty years.

Therefore, it is recommended to the Brazilian agricultural sector to maintain, prioritize, and expand the CL system in other Brazilian cities to compete in the waste management market with the CP based on criteria of sustainability of the product (agro-toxic) that already has a high environmental risk.

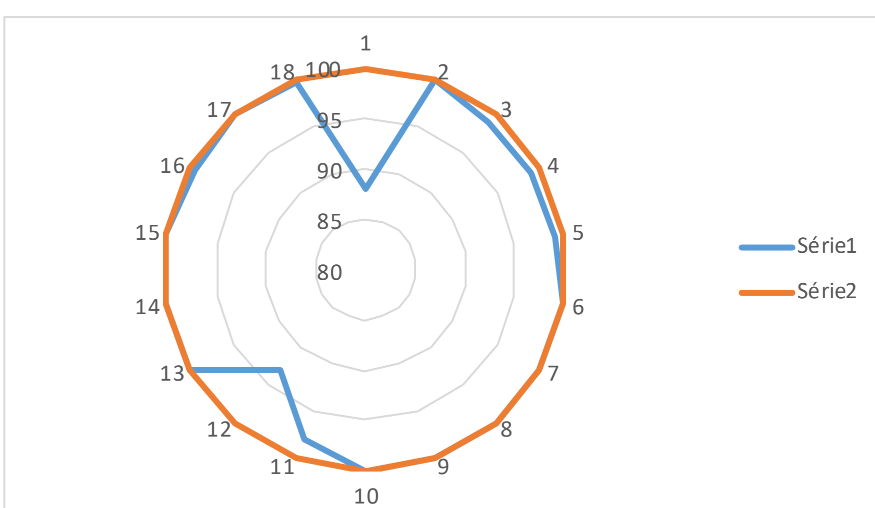

Figure 3. Percentage contribution of impact categories to CL and CP

Source: own elaboration

Revista S&G
Volume 16, Número 3, 2021, pp. 308-319
DOI: 10.20985/1980-5160.2021.v16n3.1743

It is also recommended that the cement producing sectors that use PC, the municipal and state environmental agencies, and research institutions should be more vigilant in monitoring the environmental quality parameters due to the change in the legal framework, considering, especially, the continuous monitoring of pollution and its consequent regional and local impacts.

REFERENCES

Aguiar, D.B. Mattos, U.A.O., Esteves, V.P.P. (2020). Identificação de impactos à saúde humana e ao meio ambiente nos processos de blendagem de resíduos para coprocessamento [Relatório de Pesquisa]. Rio de Janeiro. No prelo.

Associação Brasileira de Cimento Portland (ABCP). (2020), *Coprocessamento: Unidades de Coprocessamento no Brasil*. São Paulo.: https://coprocessamento.org.br/quem-coprocessa-no-brasil/.

Associação Brasileira de Empresas de Tratamento de Resíduos e Efluentes (ABETRE), (2013). *Perfil do setor de tratamento de resíduos*. São Paulo. abetre.org.br

Associação Brasileira de Normas Técnicas (ABNT). (2009). NBR ISO 14044:2009 – Gestão ambiental – Avaliação do ciclo de vida – Requisitos e orientações. Rio de Janeiro. 46 pp.

Associação Mineira De Município (AMM). (2014), *Caracterização Econômica das Regiões de Planejamento: Área de Desenvolvimento Econômico*. Belo Horizonte. https://portalamm.org.br/caracterizacao-economica-das-regioes-de-planejamento/

Braga, B. (2017). Introdução à Engenharia Ambiental: O desafio do Desenvolvimento Sustentável. 2ª ed. Editora Pearson, São Paulo.

Brasil. (2010). Lei nº 12305 de 02 de agosto de 2010. Institui a Política Nacional de Resíduos Sólidos; altera a Lei 9605, de 12 de fevereiro de 1998; e dá outras providências. *Diário Oficial da União*, Brasília, DF, p. 2, 03 ago 2010.

Comitê Da Bacia Hidrográfica Do Rio São Francisco (CBHSF). (2018). *Municípios da Bacia*. https://issuu.com/cbhsaofrancisco/docs/lista_de_munic_pios_bhsf_-_2018.xls

Comitê De Fomento Industrial De Camaçari. (COFIC). 2020. *Portal COFIC SSMA 1.0.* http://www.bameq.portalcoficssma.com.br/ConsultarProdutos/Consultar/184.

Companhia Ambiental Do Estado De São Paulo (CETESB). (2020a). *Ficha de Informação Toxicológica: Dioxinas e furanos*. São Paulo. https://cetesb.sp.gov.br/laboratorios/wp-content/uploads/sites/24/2020/07/Dioxinas-e-furanos.pdf

Companhia Ambiental do Estado de São Paulo. (CETESB). (2020b). *Qualidade do Ar: Poluentes*. São Paulo. https://cetesb.sp.gov.br/ar/poluentes/

Companhia Ambiental do Estado de São Paulo (CETESB). (2020c). *Centro Regional: Poluentes Orgânicos Persistentes.* São Paulo. https://cetesb.sp.gov.br/ar/poluentes

Conselho Estadual de Política Ambiental (COPAM). (2017). Estabelece critérios para classificação segundo o porte e potencial poluidor, bem como os critérios locacionais a serem utilizados para definição de modalidades de licenciamento ambiental e atividades utilizadoras de recursos ambientais no Estado de Minas Gerais e dá outras providências. *Diário Executivo de Minas Gerais*, 08 dez. 2017.

Conselho Nacional do Meio Ambiente (CONAMA). (2000). Resolução CONAMA nº 264 de 26 de agosto de 1999. Define procedimentos, critérios e aspectos técnicos específicos de licenciamento ambiental para o coprocessamento de resíduos em fornos rotativos de clínquer para a fabricação de cimento. *Diário Oficial da União*, Brasília, DF, n. 54, p. 80-83, 20 mar. 2000. Seção 1.

Conselho Nacional Do Meio Ambiente (CONAMA). (2020). Resolução CONAMA/MMA Nº 499 de 06 de outubro de 2020. Dispõe sobre o licenciamento da atividade de coprocessamento de resíduos em fornos rotativos de produção de clínquer. *Diário Oficial da União*, Brasília, DF, ed. 194, p. 50, 08 out. 2020. Seção 1.

Dias, M.C.O., Pereira, M.C.B., Dias, P.L.F. e Virgílio, J.F. (1999). *Manual dos Impactos Ambientais: Orientações Básicas dos Aspectos Ambientais das Unidades Produtivas*. Fortaleza: Banco do Nordeste.

European Commission - Joint Research Centre - Institute For Environment And Sustainability (JRC-IES). (2010). International Reference Life Cycle Data System (ILCD) Handbook- Framework and Requirements for Life Cycle Impact Assessment Models and Indicators.Luxembourg: Publications Office of the European Union.

Fundação Estadual do Meio Ambiente (FEAM). (2014). *Estudo de Vulnerabilidade Regional às Mudanças Climáticas de Minas Gerais.* Agência Francesa de Meio Ambiente e Gestão de Energia, Conselho Regional de Nord-Pas-de-Calais. Belo Horizonte: FEAM.

Huijbregts, M.A.J. *et al*., (2016). ReCiPe 2016, V.1.1: A harmonized life cycle impact assessment method at midpoint and endpoint level. Report I:Characterization. The Netherlands: National Institute for Public Healthand the Environment. https://www.rivm.nl/bibliotheek/rapporten/2016-0104.pdf

Instituto Brasileiro de Geografia e Estatística (IBGE). (2017a), *Produto Interno Bruto dos Municípios: Taubaté*. https://cidades.ibge.gov.br/brasil/sp/taubate/pesquisa/38/0

Instituto Brasileiro de Geografia e Estatística (IBGE) (2017b), *Censo Agropecuário: Taubaté.* https://cidades.ibge.gov.br/brasil/sp/taubate/pesquisa/24/0

Instituto Brasileiro de Informação em Ciência e Tecnologia (IBICT). (2019). *Recomendações de Modelos de Avaliação do*

Impacto do Ciclo de Vida para o Contexto Brasileiro. Rede de Avaliação do Impacto de Ciclo de Vida. Brasília-DF. Disponível em: https://acv.ibict.br/wp-content/uploads/2019/07/Relat%C3%B3rio-de-Recomenda%C3%A7%C3%B5es-de--Modelos-de-Avalia%C3%A7%C3%A3o-de-Impacto-para-o--Contexto-Brasileiro.pdf

Instituto Mineiro De Gestão Das Águas (IGAM). (2020). *Mapa Unidades de Planejamento.* Portal dos Comitês. http://comites.igam.mg.gov.br/mapa-unidades-de-planejamento.

Instituto Nacional De Processamento De Embalagens Vazias (INPEV). (2019a). *Informativo nº 81.* São Paulo: Acervo INPEV. https://inpev.org.br/saiba-mais/informativo-inpev-virtual/81/index.html

Instituto Nacional De Processamento De Embalagens Vazias (INPEV). (2019b). *Relatório de Sustentabilidade de 2019*. São Paulo. http://relatoriosustentabilidade.inpev.org.br/relatorio-sustentabilidade/2019/pt/

Instituto Nacional De Processamento De Embalagens Vazias (INPEV). (2020). *Passo-a-passo da destinação*.: https://inpev.org.br/logistica-reversa/passo-a-passo-destinacao/

Instituto Socioambiental (ISA). (2010). Área de Proteção Ambiental Cachoeira das Andorinhas. Unidades de Conservação no Brasil. https://uc.socioambiental.org/arp/2098

Intergovernmental Panel On Climate Change (IPCC). (2014). *Climate Change 2014: Synthesis Report* Geneva. pp. 151 https://www.ipcc.ch/site/assets/uploads/2018/05/SYR_AR5_FINAL_full_wcover.pdf

Lamas, W.Q., Palau, J.C.F., Camargo, J.R. (2013). Waste materials co-processing in cement industry: ecological efficiency of waste reuse. *Renewable and Sustainable Energy Reviews*. Março 2013, 19, pp. 200-207. DOI:10.1016/j.rser.2012.11.015. https://doi.org/10.1016/j.rser.2012.11.015

Matos, A.T. (2010). Poluição Ambiental: Impactos no Meio Físico. Ed. UFV. Viçosa.

Mendes, N.C., Bueno, C., Ometto, A.R. (2016). Avaliação de Impacto do Ciclo de Vida: Revisão dos Principais Métodos. *Production* 26, 1, pp. 160-175. DOI10.1590/0103-6513.153213. http://dx.doi.org/10.1590/0103-6513.153213

Ministério do Desenvolvimento Regional (MDR). (2014). *Brasil é referência na destinação correta de embalagens vazias de agrotóxicos*. https://www.gov.br/mdr/pt-br/noticias/brasil-e-referencia--na-destinacao-correta-de-embalagens-vazias-de-agrotoxicos

Ministério do Meio Ambiente (MMA). (2002). *Avaliação Ambiental Estratégica*. Secretaria de Qualidade Ambiental nos Assentamentos Humanos (SQA). Projeto Instrumentos de Gestão (Progestão), Brasília. http://mma.gov.br/estruturas/sqa_pnla/aae.pdf

Ministério do Meio Ambiente (MMA). (2014). *Política Nacional de Resíduos Sólidos apresenta resultados em 4 anos.* Departamento de Ambiente Urbano - Secretaria de Recursos Hídricos e Ambiente Urbano, Brasília – DF. https://www.gov.br/mma/pt-br/noticias/politica-de-residuos-solidos-apresenta-resultados-em-4-anos

Pinto JR., A.G. e Braga, A.M.C.B. (2009). “Trabalho e saúde: a atividade da queima de resíduos tóxicos em fornos de cimenteiras de Cantagalo, Rio de Janeiro”. *Ciênc. saúde coletiva*. Rio de Janeiro, dezembro 2009, Vol. 14, No. 6, pp. 2005-2014. DOI 10.1590/S1413-81232009000600008. http://dx.doi.org/10.1590/S1413-81232009000600008

Rocha, T.B. (2017). “Avaliação do Impacto do Ciclo de Vida”. *ACV Brasil*. https://acvbrasil.com.br/treinamentos/ead-acv

Silva, G.A., Oliveira, S.A. (2014). “Glossário de Avaliação do Ciclo de Vida”. Associação Brasileira de Análise do Ciclo de Vida (ABCV). https://docplayer.com.br/5599160-Glossario-de-avaliacao-de-ciclo-de-vida.html

Simapro Data Server. (2006). *Version 2,0803*. Release - D11 (Software). Queensland: Nexus data base ptyltd.

Simapro 7: Classroom (2010). *Version 7.2.3 Multi-user* (Software). Amersfoot: Pre-Consultantsbv.

Sistema integrado de gerenciamento de recursos hídricos do Estado De São Paulo (SIGRH). (2010), Comitê das Bacias Hidrográficas do Rio Paraíba do Sul (PS) – Apresentação. *Portal SIGRH*. São Paulo. http://www.sigrh.sp.gov.br/cbhps/apresentacao

Data availability

The entire dataset supporting the results of this study has been made available on Mendeleydata, and can be accessed at http://dx.doi.org/10.17632/zgt3g2xyfb.1

Received: August 14, 2021

Approved: November 16, 2021

DOI: 10.20985/1980-5160.2021.v16n3.1743

How to cite: Aguiar, D.B., Aluizio, U., Paulo, V. (2021). Regional environmental impacts from changing environmental legislation for co-processing of agrochemicals. Revista S&G 16, 3. https://revistasg.emnuvens.com.br/sg/article/view/1743