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Water usage in Brazil's industrial sector: estimated withdrawal, consumption, and discharge by the 30 largest industries in the country

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ABSTRACT

This study evaluated the water intake, consumption, and disposal by the 30 largest industries in Brazil, based on water consumption coefficients developed by the Agência Nacional de Águas e Saneamento Básico (ANA), technical coefficients developed by the Confederação Nacional da Indústria (CNI), and considering Brazilian annual production based on coefficients from the literature. The collected data show that, according to the volumes available in the Planilha de Outorgas, licenses were granted for the intake of 741.47 ML and for the disposal of 515.8 ML of water for the period between 2021 and 2023, considering only the companies listed in this study that requested licenses from ANA. According to the data disclosed by the companies, the intake volumes are 465,733.441 ML and the disposal volumes are 136,067.19 ML (considering only the companies that disclosed their consumption). It was not possible to establish a direct correlation between the coefficient estimates based on declared production (CNI) and those related to the number of jobs (ANA). Therefore, estimating water use using technical coefficients may be more effective by accessing data obtained directly from the industry targeted by the study or through government water resource management agencies, and for better water resource management in the country, greater transparency in data disclosure is needed, both by companies and the government.

Keywords: effluent, technical coefficients, water permits, water scarcity.

Uso de água no setor industrial brasileiro: estimativas de captação, consumo e descarte pelas 30 maiores indústrias do país

RESUMO

Neste estudo, avaliou-se a captação, o consumo e o descarte de água pelas 30 maiores indústrias do Brasil, com base nos coeficientes de consumo hídrico elaborados pela Agência Nacional de Águas e Saneamento Básico (ANA), com base nos coeficientes técnicos elaborados pela Confederação Nacional da Indústria (CNI) e considerando a produção anual brasileira com base em coeficientes da literatura. Os dados coletados mostram que, segundo os volumes disponíveis na Planilha de Outorgas, foram concedidas licenças para a captação de 741,47 ML e para o descarte de 515,8 ML de água para o período entre 2021 e 2023, considerando apenas as empresas listadas neste estudo que solicitaram licenças à ANA. De acordo com os dados divulgados pelas empresas, os volumes de captação são de 465.733,441 ML e os volumes de descarte são de 136.067,19 ML (considerando apenas as empresas que divulgaram seu consumo). Não foi possível estabelecer correlação direta entre as estimativas dos coeficientes com base na produção declarada (CNI) e àquelas relacionadas ao número de empregos (ANA). Portanto, a estimativa do uso da água utilizando coeficientes técnicos pode ser mais eficaz acessando dados obtidos diretamente da indústria alvo do estudo ou por meio de agências governamentais de gestão de recursos hídricos, e para uma melhor gestão dos recursos hídricos no país, é necessária maior transparência na divulgação de dados, tanto por parte das empresas quanto do governo.

Palavras-chave: coeficientes técnicos, efluente, escassez hídrica, outorga de uso de água.

Abbreviations: Agência Nacional de Águas e Saneamento Básico (ANA), Confederação Nacional da Indústria (CNI); averages of ANA technical coefficients (AATC); averages of the CNI technical coefficients (ACTC); withdrawal according to CNI (WCNI); withdrawal number of employees according to ANA (WEA); withdrawal "Planilha de Outorga" of ANA (WPO); withdrawal disclosed by companies (WDD); discharge of CNI agreement (DCNI); discharge "Planilha de Outorga" (DPO); discharge disclosed by companies (DDD); discharge according to number of employees (DEA); Consumption according to the number of employees (CEA); consumption according to CNI (CCNI); consumption according to data published by companies (CPC); not applicable (NA); undisclosed data (UD); global data disclosure (GDD).

1. INTRODUCTION

Among the challenges faced by the world's populations, in addition to climate change and energy consumption, is the management of water resources, particularly water scarcity. One factor contributing to the worsening of these problems is population growth and industrialization (Chauhan and Ahn, 2023). Rapid economic growth associated with the gradual improvement of living standards, as well as adjustments in economic and industrial structures, has led to increased demand for industrial water (Zhang *et al.*, 2022).

Worldwide, the demand for water by the industrial sector is linked to the type of product or service generated and the industrial processes used. It depends on several factors, such as the type of process used in production, the technologies employed, the practices implemented, and the stage of management modernization. It may also be affected by the type of raw materials, reagents, and operations involving washing and heat transmission (ANA, 2017).

In Brazil, the industrial sector accounts for 69.2% of exports and investments in R&D. This segment is a major job generator, employing 9.7 million Brazilians and representing 20.4% of formal jobs in the country (Portal da Indústria, 2024). Despite its significant employment rate, the industrial sector is responsible for only 9.4% of water withdrawal, following irrigation (50.5%) and urban supply (23.9%). The remaining water usage is distributed among animal use (8%), thermoelectric plants (5%), rural supply (1.6%), and mining (1.6%). In 2022, the estimated volume of water withdrawn was 2,035.2 $m^3 s^{-1}$ or 64.18 trillion liters per year (ANA, 2024).

Among the segments with the highest levels of water consumption is the sugar and alcohol industry. Brazil is the world's largest producer of sugarcane and the main exporter of sugar and ethanol. In this chain, which includes companies that produce sugar or alcohol or are part of the production chain of these products, in 2015 alone 54.55 $m^3 s^{-1}$ and 2571 $m^3 s^{-1}$ of water were consumed for the production of sugar and biofuels, respectively (ANA, 2024).

Another sector significantly impacting water consumption is agribusiness. Projections indicate a continued increase in extensive water use, mainly for irrigation, with a tendency for competition between this segment and other economic sectors to rise. The scenario worsens when considering the growing scarcity of water, exacerbated by drought and climate change (Mancosu *et al.*, 2015).

In Brazil, the diverse geographic and climatic landscapes, combined with varying socioeconomic realities, create unique water management challenges (Santos *et al.*, 2023). According to the ANA database, approximately 240,000 water bodies have been mapped in the country, of which 3,661 are artificial reservoirs with a total storage capacity of 630.2 billion m³. Of this total, 92.7% are reservoirs for hydroelectric power generation. Of the country's total water storage capacity, approximately 266 billion m³ is located in the Paraná basin (Paraná, Iguaçu, Paranapanema, Grande, and Paranaíba), Tocantins-Araguaia, and São Francisco (ANA, 2024).

It is undeniable that, in a scenario of rapid industrial development and increasing water demand, analyzing usage patterns is an important tool for water resource management. This analysis can prevent water shortages and optimize consumption. Understanding the factors that directly influence industrial water consumption and forecasting demand promotes rational water use by industry and the sustainable development of both the industrial economy and water resources (Zhang *et al.*, 2022).

In this work, the collection, consumption, and disposal of water by the 30 largest industries in the country were assessed based on water consumption coefficients prepared by ANA, which considers the number of employees in its consumption rates; by the National Confederation of Industry (CNI), which uses the industry's annual production as the basis for its coefficients; and by rates published in international scientific studies. In addition, the results were compared with data published by the companies, primarily through their sustainability reports and collection and disposal data from ANA's grant reports.

2. MATERIAL AND METHODS

This study evaluated water use by the 30 largest industries in Brazil, considering withdrawal (volume of water withdrawn from water sources and/or collected from water supply companies), consumption (volume retained during the manufacturing process, whether by evaporation, retained in the product, or reused in other processes), and disposal (volume destined for the treatment system or discharged into water bodies), by the main Brazilian sectors. The industries were selected based on the ranking of the largest companies in Brazil, according to the Estadão magazine article "Ranking 1500: Recognizing the Largest Companies in the Country by Size (2024)" (Estadão, 2024), which is based on the net profit obtained by the companies in 2023. To estimate water use (in megatons or megaliters) by the selected industries, three approaches were used, as follows:

1) Based on the technical coefficients of the "*Matriz de Coeficientes Técnicos de Vazões de Retirada, Consumo Lançamento de Efluentes*" prepared by the Confederação Nacional da Indústria (CNI). This approach considers the annual production of industries and the type of product manufactured, available in "*Uso da Água no Setor Industrial Brasileiro: Matriz de Coeficientes Técnicos*" (CNI, 2013).

The preparation of the matrix of technical coefficients for water use in the industrial sector was a project developed by Funarbe/Federal University of Viçosa and Banco do Brasil Foundation, with support from the Industrial Water Resources Network, and published by the Confederação Nacional da Indústria. The study began in 2009 and was completed in 2011. The coefficients used to estimate water use (withdrawal, consumption, and discharge) were based on the cubic meter of water per ton of product obtained (CNI, 2013).

2) The "*Coeficientes Técnicos para a Indústria de Transformação*" prepared by *Agência Nacional das Águas e Saneamento Básico (ANA)*, as available in the document "*Água na Indústria: Uso/Demanda e Coeficientes Técnicos*" was used for the calculations. This

coefficient considers the number of employees working in a given production segment. The estimate of the volumes raised and launched, based on the number of employees, was made considering the total number of employees, regardless of their occupation within the industry (Table S2).

3) Additionally, data on water intake and discharge were extracted from the *Outorgas Federais* spreadsheets published by ANA in "*Outorgas Emitidas*" (ANA, 2024). The compilation of ANA spreadsheets related to licenses was based on the selection of licenses valid from 2020 onwards, focusing on licenses related to the right to use water for intake and discharge. Preventive licenses and reference points were excluded. Data on the number of employees and annual production for the years 2021, 2022, and 2023 were obtained from company websites, primarily from their sustainability reports.

For the calculations performed using the technical coefficients, the determination of the volumes of water intake, consumption, and discharge was based on the types of industrial activities contained in the document "Divisões do CNAE - Classificação Nacional de Atividades Econômicas 2.0".

The results obtained for water withdrawal according to the Confederação Nacional da Indústria (CNI) (WCNI), number of employees according to the ANA (WEA), water intake licenses issued by the ANA (WPO), and water withdrawal declared by companies (WDD) were compared. Discharge volumes according to the CNI (DCNI), license spreadsheet (DPO), discharge declared by companies (DDD), and number of employees from the ANA (DEA) were also compared. In addition, consumption according to the number of employees (CEA), according to the CNI (CCNI), and according to data declared by companies (CPC) was compared. Data comparison was performed to determine if the values declared by the companies are in accordance with the data released by government agencies and the coefficients.

Finally, the volume of water needed for the operation of the country's main industrial sectors related to the listed industries was estimated. The demand estimate (volume capable of supplying the needs of industries), was obtained considering the annual Brazilian production reported in the media, mainly by industrial associations, government websites, and the ETENE Caderno Setorial ETENE. For the calculation of volumes, consumption coefficients available in the scientific literature, mainly national, were used. However, for products whose coefficients were not identified based on Brazilian production, a coefficient from international scientific literature was used. In all calculations of water volumes captured, consumed, or discarded, regardless of the coefficient, the volume of water in megaliters (ML) necessary to obtain one ton (t) or megaton (Mt) of product was considered. This approach aims to estimate the total volume of water needed to supply the studied segments and offer society an overview of water uses in Brazil.

3. RESULTS AND DISCUSSION

3.1. Withdrawal (WPO) and discharge (DPO) of the Federal Ourtogas Worksheets by ANA

In this work, according to data from the Federal Outorgas Worksheets by ANA, among the industries evaluated, the withdrawal forecast between 2021 and 2024 was 741.47 ML. The withdrawal percentages among the sectors and companies registered in the Federal Outorgas Worksheets are described in the graph in Figure 1a.

Figure 1a shows *Companhia Siderúrgica Nacional* (CSN), Klabin, and Raizen as the industries with the highest water withdrawal volumes, totaling 81.3% of the volume captured by the studied industries (WPO). The highest predicted withdrawal volume was for CSN, a steel manufacturing industry. As stated by CNI in 2013, the average water consumption of Brazilian industry varies between 1.25 and 52.5 m^3 per ton of product. According to Conejo *et al.* (2020), developed countries consume between 3 and 4 m³ t^{-1} in steel production. In China, one of the largest producers in the world, the average consumption is between 7 and 8 m³ t^{-1} of steel. For the authors, the significant difference relates to the technologies involved, including equipment, processes, and outdated industrial plants still in use since the 1980s. This results in obsolete technologies and unoptimized water use and processes.

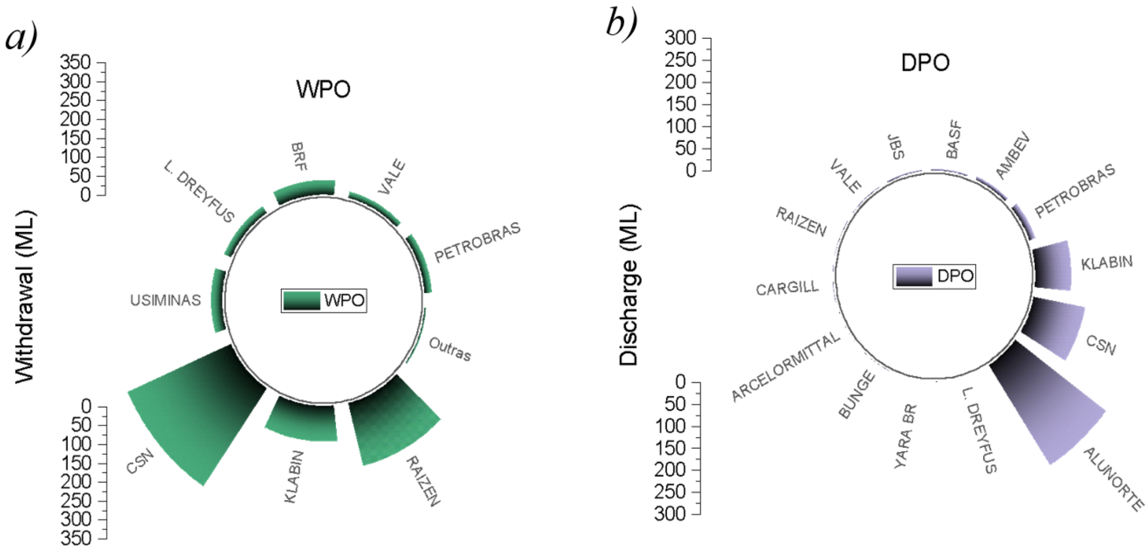

Figure 1. (a) Annual water withdrawls releasing in ML according to the ANA – *Planilha de Outorga* (WPO) (b) Wastewater discharge volumes in ML according to the ANA – *Planilha de outorga* (DPO).

The steel chain involves steelmaking technology and processes that are very demanding in terms of energy and water. According to the concept of water carrier and water value, which considers water quality levels, the amount consumed in the steelmaking process can reach around 129 m³ t^{-1} of final steel products. In the chain, the processes that demand the most water are rolling, coking, steelmaking, and casting, consuming 44, 32, 20, and 13 m t^{-1}, respectively. These values are determined through water value analysis (Klimeš *et al.*, 2020).

Klabin and Raizer, in the paper and food industries respectively, also produce ethanol and sugar from sugarcane, representing 37.3% of the water withdrawal permits expected to be valid between 2021 and 2024. The significant volume of water withdrawal permits for these industries may be related to the products processed. According to ANA 2024, in the Brazilian manufacturing industry, sectors with high levels of water consumption include sugarcane, pulp and paper, slaughter and meat products, and alcoholic beverages (ANA, 2024).

In addition to water withdrawal and discharge, the permits include the damming of water bodies. It is important to highlight that of the 30 companies registered in the Planilha Federal de Outorgas (Table S1), seven have a planned withdrawal volume lower than 1% of the total WPO. These companies are Garcil, Bunge, Arcelormittal, Ambev, Suzano, Basf, and Gerdau. For the 30 industries evaluated, the total volume collected was 741.47 ML. Discharge is necessary when the industry cannot find uses for this water due to the quality required for its introduction into other processes (ANA, 2024). In this study, dams were not considered in the accounting of water use.

Based on the data from the permit applications, the largest estimated discharge volume is attributed to Alunorte, accounting for just over half (52.1%) of the total volume granted to the studied industries (Figure 1b). Alunorte, Hidro group, produced 6.2 megatons of alumina in 2022. In second place for wastewater discharge (WPO), with 24.2% of the volume, is CSN. Both companies operate in the metallurgy and steel segments, which are characterized by large volumes of wastewater production, contributing substantially to the overall volume produced by these industries. In the steel production chain, the process that generates the most effluents include obtaining pig iron (from smelting in blast furnaces), rolling mills, and Linz-Donawitz (LD) converters (Chalaris *et al.*, 2023). In third place for wastewater discharge is Klabin, with 16.6% of the total volume. The three largest wastewater emitters (Alunorte, CSN, and Klabin) account for 92.9% of the total volume granted to the companies studied (479.85 ML of effluents).

Discharge data released by ANA reveal that in 2022, a total flow of 131 $m^3\ s^{-1}$ was granted in waters under the jurisdiction of the Union, and this year another 26.1 $m^3\ s^{-1}$ were granted, with almost half of the releases (47%) granted to the industry. Regarding capitation, the volume granted to the industry was 16.336 $m^3\ s^{-1}$, with 361 $m^3\ s^{-1}$ under Federal jurisdiction and 15.856 $m^3\ s^{-1}$ under State jurisdiction (ANA, 2024).

3.2. Withdrawal (WEA), consumption and discharge (DEA) according to number of employees (ANA Matrix)

Considering the companies evaluated, the total withdrawal volume would be approximately 1,056,095.10 ML, based on the average between the lowest and highest coefficients suggested by the ANA coefficient matrix (AATC) (Table S3). Based on the number of jobs in the selected industries, Figure 2a and 2b presents the estimated percentage of annual water withdrawal (WEA) and discharge (DEA) permits according to the ANA.

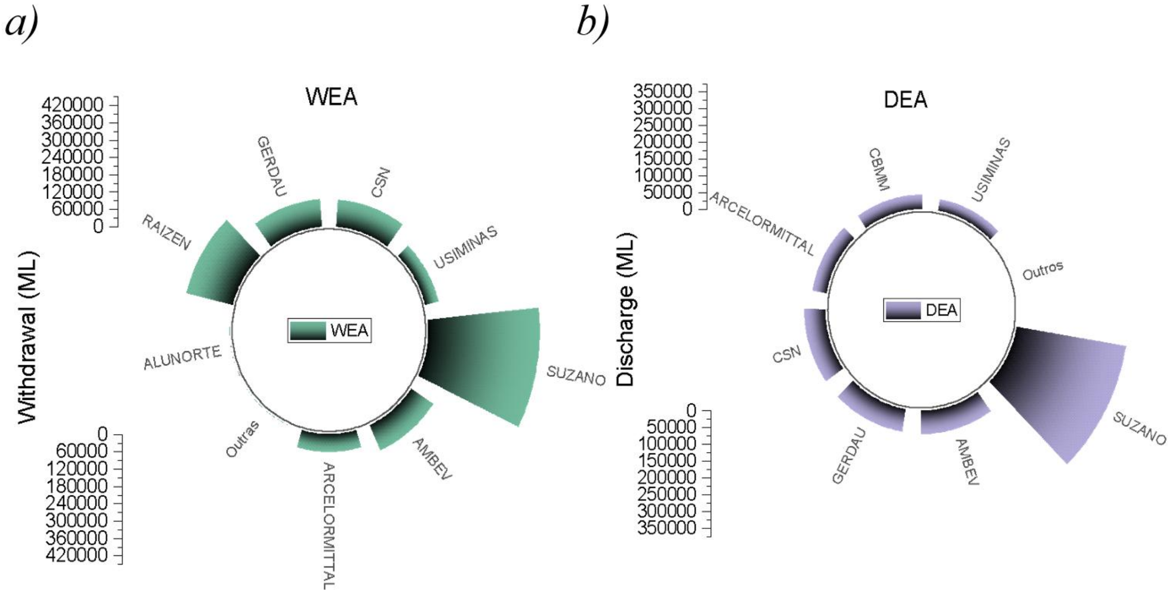

Figure 2. Estimate based on the number of industry jobs in relation to annual water withdrawal (a) and discharge (b) according to the ANA (Coefficient Matrix) in ML.

Figure 2a shows that the leader in water capture is Suzano, with 20,627 employees, responsible for withdrawing 404,993.82 ML, representing more than 40% of the total estimated volume. All processes, such as raw material preparation, pulping, pulp washing and screening, bleaching, stock preparation, paper manufacturing, and chemical recovery, require water use in the pulp and paper industry. According to the literature, high consumption is partly caused by obsolete technologies and processes, which persist due to the high cost of upgrading at scale (Pathak and Sharma, 2023).

In second place in terms of water capture is Raizen (26,783 employees), which also appears as one of the main water capturers according to Planilha de Outorga (PO). Worldwide, the sugarcane industry is characterized by the high generation of labor and several essential products, such as sugar, ethanol and bagasse, contributing 29% of the world's total agricultural production. Despite its importance, the sugar and alcohol sector in its two main stages, agriculture and manufacturing, consumes a significant volume of water and generates a lot of effluent (Jorrat *et al.*, 2018). According to the number of employees, Raizen is responsible for the estimated capture of 173,932.12 ML of water, which represents 18.9% of the total estimated volume considering the AATC. The company identifies itself as a global reference in bioenergy, being among the largest private business groups in Brazil, also operating in Argentina and Paraguay.

Considering the study period, the estimated withdrawal volume for the group of 30 companies was approximately 1,056,095.1 ML according to AATC. The data indicate that more than 20% of this volume was allocated to irrigation since Raizen (18.9%) operates in the agribusiness sector and Suzano (40.7%) uses part of the water withdrawal to irrigate eucalyptus plantations used in pulp production. According to the ANA, in 2024, the withdrawal in 2022 destined for irrigation alone corresponded to 79% of the total flow granted (ANA, 2024). On the other hand, the annual water consumption was estimated at 377,273.86 ML for the 30 industries studied. This volume corresponds to 35.72% of the allocated fraction. According to the ANA, water consumed in the industrial process is the fraction that is incorporated into the product, evaporates, or is made available for reuse or other purposes; therefore, it does not return to the water body or is not directed to the effluent treatment system (ANA, 2013).

The estimated discharge involved approximately 678,821.24 ML for the set of industries (AATC). As shown in Figure 2b, the segment with the highest estimated discharge is the pulp and paper industry, accounting for just over half of the discharge. Suzano's wastewater discharge is estimated at approximately 346,350.80 ML, representing 51.02% of the total estimated volume. The pulp and paper production segment is associated with the consumption of approximately 10 to 20 m^3 of water per ton of final product and is responsible for high water discharge. Pulp production is the most environmentally hazardous process due to the formation of waste liquors, which are wastewater containing lignosulfonates. These compounds are difficult to treat and present a significant technological problem as they do not undergo biological degradation, significantly reducing the efficiency of water purification and increasing the volume of wastewater (Vaysman *et al.*, 2018).

Ambev (29.239 employees) and Gerdau (26.783 employees) together are responsible for producing 20.56% of the total effluent estimated for the 30 industries studied (AATC). Ambev operates in the beverage industry and is the largest brewery in Latin America, considering sales volume. The company operates in 18 countries in the Americas in the manufacture, distribution, and sale of various products such as beer, soft drinks, non-alcoholic, and non-carbonated products. The company also owns two beer brands that are among the 10 most consumed globally and is one of the largest independent bottlers of PepsiCo worldwide (Ambev, 2024). Gerdau is the largest Brazilian multinational in the steel production segment, serving sectors such as construction, automotive, machinery, naval, energy, and others. The company operates in several Latin American countries and is a leading supplier of long steel in the Americas and special steel globally. It is also the largest producer of charcoal worldwide. In steel production, the company has 29 units (Gerdau, 2024).

Estimating the spatial distribution, demand, and use of water by industry is a challenge. Among the most notable problems are uncertainties due to the lack of systematized flow databases and inconsistencies in permit data. These and other factors corroborate that indirect estimates are necessary to address this problem (ANA, 2017). Among the indirect methods used are estimates that utilize the number of employees to calculate capture, consumption, and discharge for the industrial sector, using coefficients provided by ANA. However, the number of employee identifications in some industries is still insufficient because some companies do not disclose complete information.

It was not possible to identify the number of employees in some industries in this work because some companies do not disclose this information, while others present general data without specifying the sectors they operate in. Additionally, some industries disclose data involving subsidiaries located outside Brazil, as is the case with multinationals such as Anglo Ferrous Minas-Rio or Anglo American Minério de Ferro and Klabin, which disclose the number of global employees.

In general, the industrial segment registered 11,004,473 employees in 2022, with the record holders in number being Amazonas (148,647), Piauí (60,495), and Sergipe (72,485). Among the occupations with the highest concentration of employees are packers and production feeders, construction and public works workers, and construction assistants, responsible for 1,088,501 (9.89%), 762,369 (6.93%), and 544,003 (4.94%) of employees in the segment, respectively. The percentages refer to the total jobs in the period (SEBRAE, 2024).

3.3. Withdrawal (WCNI), consumption (CCNI), and discharge (DCNI) according to production (CNI Matrix)

The results of this study indicate that the total volume of water withdrawal for the 30 companies studied was approximately 8,542.33 ML, considering the annual productions for the periods between 2021 and 2023 and the averages of the maximum and minimum coefficients. However, this volume reflects a partial result, as it was not possible to identify the annual production specific to Brazil for some companies, such as multinationals Vale, JBS (JBS Couros), BRF, and Louis Dreyfus BR. Additionally, for Refmat and Basf, data were not available in the media. For other industries, it was not possible to estimate the uses because they produce products that fit into different typologies. For example, Ambev produces alcoholic beverages (coefficient 11.1) and non-alcoholic beverages (coefficient 11.2), while Spal, Raizen Alimentos, and Minerva Foods produce food and beverages or diversified foods (coefficient 10). In the case of Petrobrás, Alunorte, Shell, and Petrogal, it was not possible to obtain estimated usage data because their activities resulted in products whose coefficients were not determined in the CNI matrix. Out of the total estimated withdrawn volume, Suzano would be responsible for 2,996.80 ML of withdrawal, accounting for 35.1% of the combined total from all industries. In second and third place for withdrawal would be BP Bunge and Yara Br, with 2,422.1 ML and 1,022.40 ML, respectively (Table S4). Withdrawal, consumption, and discharge involving all industries (CNI) are detailed in Table 1 and Figure 3.

Regarding water consumption during manufacturing processes, the company with the largest volume retained is BP Bunge, with 2,422.1 ML, representing 28.35% of the total consumption of 8,542.33 ML. Considering all companies with computed data, the percentage of water retained during the process is 47.47%. The discharge involves 4,486.6 ML of wastewater. Although the technical coefficients were derived from the Brazilian context, usage patterns involving water intake, consumption, and disposal vary according to the technology used in the production process and the water use management adopted by the company (CNI, 2013). These factors can cause distortions in consumption estimates and predictions, potentially overestimating or underestimating the volumes needed for each segment. Despite this risk, estimation using this method, based on data segmented by types of manufactured products, helps in determining water resource management policies targeted to each sector.

Table 1. Correlation of companies with their respective products obtained, annual production, calculation of the estimated value through the technical coefficients matrix of the Confederação Nacional da Industria (CNI) based on the Divisões do CNAE - Classificação Nacional de Atividades Econômicas (CNAE 2.0), and volumes disclosed by companies.

Industry	Product	CNE 2.0 * Classification			Annual production	Calculation of estimated volume			Volume disclosed by companies			Year	Reference
		Division	Group	Class		Withdrawal	Consumption	Effluents	Collection	Consump.	Effluents (ML)		
Petrobras* and *Petrobras Biocombustíveis (biodiesel)	Oil	NCC	-	-	2.245 Mbbl day^{-1}	NA	NA	NA	GDD	GDD	GDD	-	-
	Natural gas	NCC	-	-	100479.61 Mm^3 day^{-1}	NA	NA	NA	GDD	GDD	GDD		
Vale	Iron ore	7	7.1	-	321Mt	**337.05**	**57.78 to 321**	**279.27**	GDD	GDD	GDD	2023	-
	Pellets		7.2	-	GDD	-	-	-					
	Nickel		-	07.29-4	GDD	-	-	-					
	Copper		-	07.29-4	GDD	-	-	-					
Cargill (divisão agrícola)	Food and beverages	10 and 11	-	-	125.6 Mt (soya)	-	-		UD	UD	UD	2022	
BP Bunge Energia	Bioethanol Alcohol	19	19.3	-	1200 ML	**2400**	**2400**	**-**	**29006.8**	UD	UD	2022	(BP Bunge Bioenergia, 2023)
	Sugar	10	10.7	-	1.3 Mt	**22.1**	**22.1**						
Bunge alimentos	Diversified foods	10	-	-	GDD	NA	NA	NA	GDD	GDD	GDD	2022 2023	-
Braskem	Polyethylene	20	20.3	-	UD	NA	NA	NA	UD	UD	UD	2022	-
Shell brasil	Oil	NCC	-	-	361419.66 bbl day^{-1}				GDD	GDD	GDD	2024	-
	Natural gas				16735.15 Mm^3 day^{-1}	NA	NA	NA					
Arcelor mittal	Iron ore	7	7.1	-	3.300 Mt	**3.465**	**0.59 to 3.3**	**2.871**	**403908.2**	UD	**372921.64**	2022	(ArcelorMittal Brasi, 2023)
	Steel	24	24.2	-	12.700 Mt	**426.72**	**110.49**	**316.23**					

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Refmat	Chemicals and petrochemicals	20	-	-	UD	-	-	-	UD	UD	UD	-	-
JBS (Friboi, Seara, JBS couros)	Beef protein (*Friboi*)	10	10.1	10.11-2	2.970 Mt	**5.94**	**0.7425**	**5.1975**	GDD	GDD	GDD	2022	-
	Poultry protein (*Seara*)			10.12-1	1.5 Mt	**6.0 to 18**	**2.25**	**5.25 a 15.75**					
	Leather (*JBS Couros*)	15	15.1		GDD	-	-	-					
BRF	Food and beverages	10 and 11	-	-	GDD	-	-	-	GDD	GDD	GDD	2023	-
Louis Dreyfus BR	Food and beverages	10 and 11	-	-	GDD	-	-	-	GDD	GDD	GDD	2022	-
Ambev	Alcoholic and non-alcoholic beverages	11	11.1 e 11.2	-	12.64 ML	NA	NA	NA	40671.5	2.54 hL $(hL_b)^{-1}$	26053.69	2022	(Ambev, 2023)
Suzano Papel e Celulose	Cellulose	17	17.1	-	10.2 Mt	**264.2 to 477.4**	**34 to 59**	**232 to 418**	**318248**	**64000**	UD	2023	(Suzano, 2023)
	Paper, cardboard and cellulose derivatives		17.2	-	e 52 kt	**1976 to 3276**	**208 to 1092**	**1768 to 2184**					
Yara Brasil	Chemicals and petrochemicals	8	8.9	08.91-6	32 Kt	**524.8 to 1520**	**211.2 to 441.6**	**82.2 to 1177.6**	UD	UD	UD	2023	-
Usiminas	Steel	24	24.2		a 4 Mt	**134.4**	**34.8**	**99.6**	**55.8**	**53.81**	**37.01**	2023	(Usiminas, 2023)
	Iron one	7	7.1	-	8.8 Mt	**9.24**	**1.58 to 8.8**	**7.656**					
Companhia Siderúrgica Nacional (CSN)	Cement	23	23.2	-	13 Kt	**1 to 5.2**	**2 a 5.2**	**-**	GDD	GDD	GDD	2023	-
	Steel	24	24.2		4.2 Mt	**141.12**	**36.54**	**104.58**	GDD	GDD	GDD		
	Iron ore	7	7.1		to 42.6 Mt	**44.73**	**1.58 to 8.8**	**37.062**	GDD	GDD	GDD		

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BASF	Chemicals and petrochemicals	20	-	-	UD	**2800**	UD	UD	UD	UD	UD	2023	(Basf, 2024)-
Gerdau Cosigua	Steel	24	24.2	-	5.4 Mt	**181.44**	**46.98**	**134.46**	**4017.4**	UD	**1300.49**	2022	(Gerdau, 2023)
	Iron ore	7	7.1	-	5.8 Mt	**6.09**	**1.58 to 8.8**	**5.046**					
Klabin	Paper	17	17.1	-	1.6 Mt	**41.44 to 74.88**	**5.2 to 9.28**	**36.32 to 65.60**	**119368**	**15858**	**103510**	2022	(Klabin, 2024)
	Cellulose		17.2	-	4.6 Mt	**46 to 212.98**	**8.28 to 36.64**	**37.72 to 174.34**					
Petrogal Brasil (GALP)	Oil	NCC	-	-	95318.82 bbl day^{-1}	NA	NA	NA	GDD	GDD	GDD	2023	-
	Gas				4295.88 $Mm^3\ day^{-1}$	NA							
Spal (Coca-cola Femsa)	Food and beverages	10 ou 11	-	-	a 4.970.000 ML	NA	NA	NA	[a]7157	UD	UD	2022	(Coca-Cola FEMSA Brasil, 2023)
Minerva Foods	Processed foods	10	-	-	458.36 Kt	NA	NA	NA	UD	**1150.3**	UD	2023	(Minerva S.A., 2024)
		NA	-	-	18.39 Kt	NA	NA	NA					
	Leather	15	15.1	-	89.86 Kt	**42.23 to 89.86**	**0.035944**	**35.94 to 89.86**					
	Biodiesel	NCC	-	-	51.7 Kt	NA	NA	NA					
Raizen Energia	Sugar	10	10.7	-	4.78 Mt	**81.26**	**81.26**	**-**	**67836**	**62670**	**5166**	2023	(Raizen, 2023)
	Alcohol	19	19.3	-	6.78 Mt	**13.56**	**13.56**	-					
Anglo Ferrous Minas-rio	Nickel	7	7.2	7.29-4	9.9 Kt	**18.414**	**15.642**	**2.772**	UD	UD	UD	2022	-
	Iron	7	7.1	-	6.3 Mt	**6.615**	**1.134 to 6.3**	**5.481**					
Continue...													

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Hydro (Alunorte)	ALUNORTE (aluminium refinery)	NA	-	- -	6.2 Mt	NA	NA	NA	11.7	-	-	22022	(Hydro Alunorte, 2024)
CBMM (Companhia Brasileira de Metalurgia e Mineração)	Metallurgy and Steel Industry	24	24.4	-	99.463	**123.33tto 348.12**	**24.87 to 69.62**	**98.47 to 278.5**	**3098**	**2269**	**3544**	2022	(CBMM), 2023)

* Division of the National Classification of Economic Activities (CNAE 2.0)
** Undisclosed data (UD); Not Applicable (NA); Global data disclosure (GDD)
*** Thousand barrels of oil (MBBL); Barrels of oil (BBL)

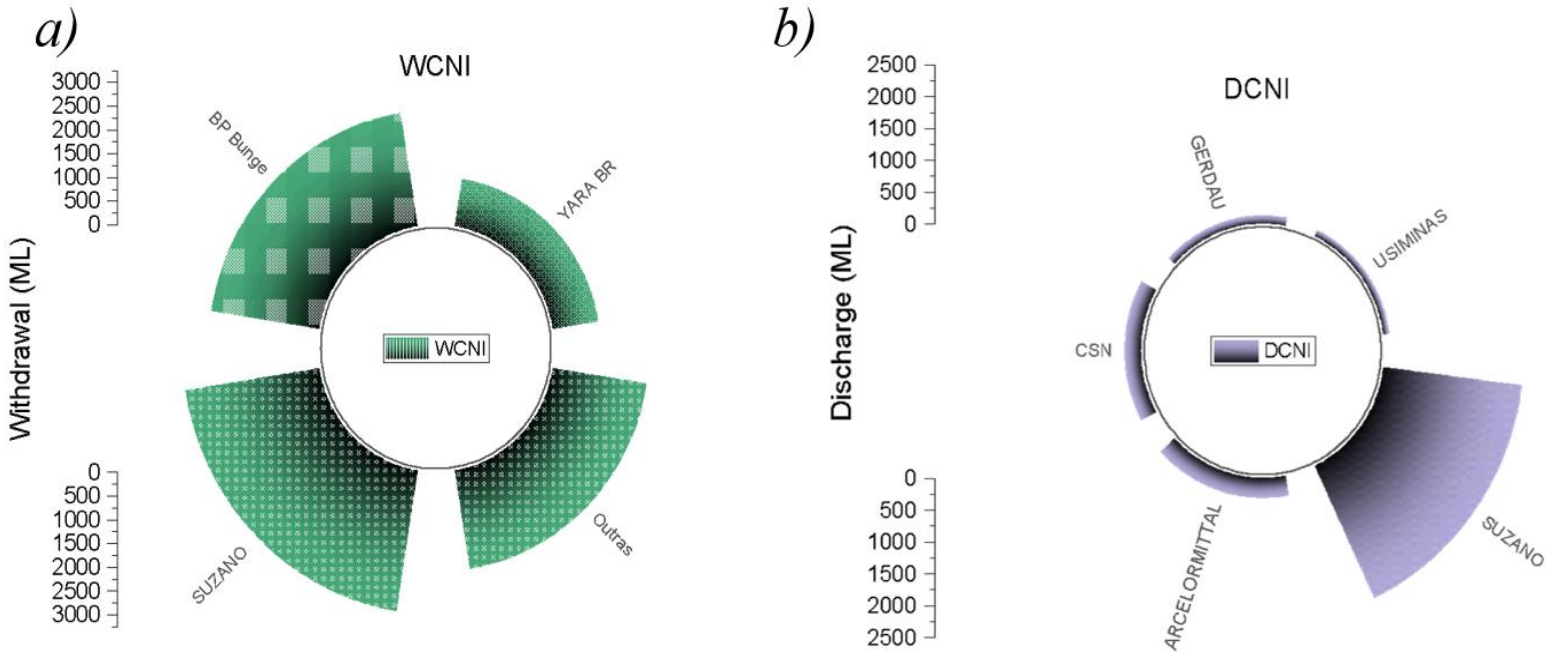

Figure 3. Estimate considering the annual productions in relation to annual water withdrawal (a) and discharge (b) according to the CNI (Coefficient Matrix) in ML.

3.4. Withdrawal (WDD), consumption (CDD) and discharge (DDD) announced by the company

Considering the data disclosed through the companies' sustainability reports or websites, it was possible to determine the total withdrawal, consumption, and discharge volumes at 462,933.44 ML, 130,286.94 ML, and 34,929.34 ML, respectively. The reported volumes describe partial results since only 30% of the companies investigated published water use by country. Some companies with facilities in multiple countries, such as Petrobrás, Vale, ArcelorMittal, BRF, L. Dreyfus, CSN, and Petrogal, report their usage on a global scale. For some industries, it was not possible to identify data in the media, including Garcil, Braskem, Refmat, Yara Br, Minerva Foods, and A. Ferrous. As shown in Figure 4a, among the industries that disclosed their usage, Suzano has the highest capture percentage, withdrawing over 53.7% of the total volume. Klabin is in second place with 20.2% of the volume collected. Two companies are responsible for capturing 526,616 ML of water, representing 89.4% of the total volume. Both companies operate in the pulp and paper segment and agribusiness sector.

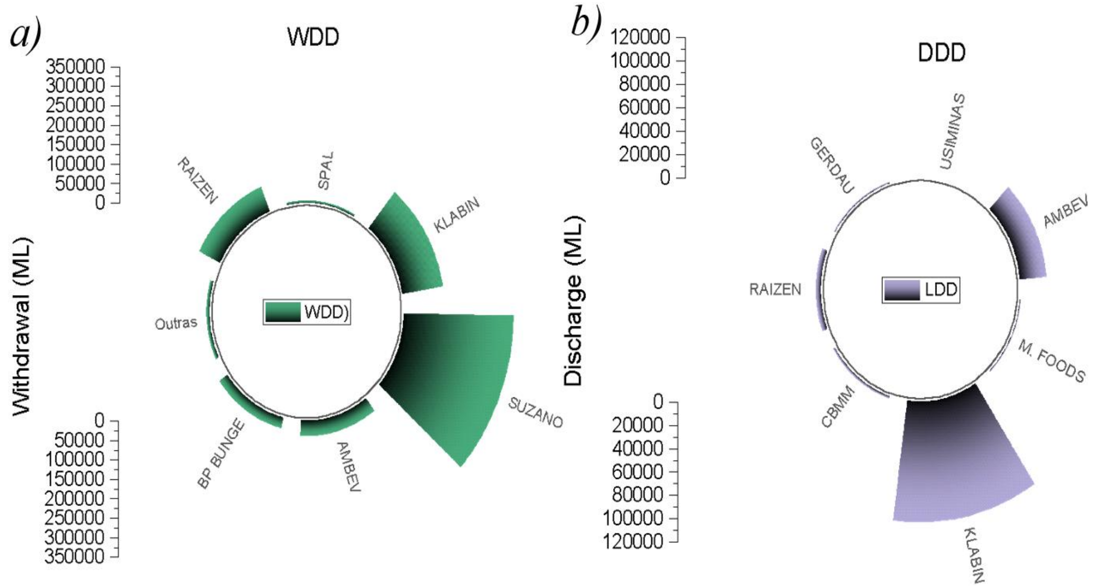

Figure 4. Volume of annual water withdrawal (a) and discharge (b) according to company disclosure data.

The company with the largest discarded volume is Ambev, with 26,053.69 ML reported. In second place is Raizen, with 5,166 ML discarded. These companies account for 89.4% of the discarded volume reported by the companies studied, which operate in the food and beverage segment. The food sector is one of the fastest-growing segments globally, and as a result, supply and consumption generate high discharges of wastewater and unwanted waste, mainly by the beverage, meat, fish, seafood, and dairy industries (Morker *et al.*, 2023). The volume of water retained, or that which does not return to water bodies, is rarely reported by companies. Among the industries with available data, M. Foods has the highest retained volume, with 1,150.27 ML of water consumed. M. Foods is a company that produces and exports beef and also operates in the processed food segment, with facilities in other Latin American countries and Australia (Minerva Foods, 2024).

3.5. Comparison between results

The indexes obtained through the CNI and ANA coefficients, as well as the values in the "spreadsheets permits" and the volumes disclosed by the companies, were compared to estimate the differences between them. However, due to a lack of data disclosed for all the companies studied, whether regarding the number of employees or production volume, few results could be compared. It is also important to highlight that some companies work with a wide variety of products and do not make available the volumes obtained annually by type. The companies Vale, Garcil, and BP Bunge disclosed production data in their sustainability reports; however, the number of employees working only in Brazil is not available in the media.

To understand the relationship between the withdrawal volumes reported by companies and those in the Planilha de Outorgas, it was considered that some companies disclose total volumes collected, regardless of the source. Others specify volumes taken from surface water, underground sources, and supply companies. For example, Ambev reported collecting 20,370.71 ML from surface water, 14,904.88 ML from underground sources, and 5,395.92 ML from third-party sources, totaling 40,671.51 ML in 2022. As the data in the spreadsheets used in this study only deal with the volume collected in federal domains, the volumes disclosed in the permits spreadsheet and those disclosed by the companies should diverge, with the granted volumes tending to present lower values than the collection volumes disclosed by the companies. Therefore, the results obtained in this study are consistent with the hypothesis raised, implying that the companies must have used water sources managed by the States or the Federal District and/or other supply sources.

From graph (Figure 5a), it is evident that the largest water collectors, both in the permits spreadsheet (Klabin) and in the published volumes (Suzano), require water for irrigation. In 2020, a permit for approximately 31 trillion liters was granted for irrigation (7% from underground sources and 93% from surface water), with the states and Federal District responsible for 58% of this volume and the Union (ANA) responsible for the remaining 42%. Irrigation, in addition to requiring large amounts of water for its maintenance, demands good quality water. In this context, water wasted in other sectors and previously contaminated in other crops or sectors can limit the amount available, mainly for food production (ANA, 2021). One factor to consider when analyzing the graphs in Figure 5 is that to display the estimated values in the respective comparisons, when the disparity between the lowest and highest values was extremely significant, it was necessary to present the company data on two different axes for each coefficient, with the left axis showing values starting with negative numbers. This allowed the results to be displayed in a single graph, effectively illustrating how these data relate to each other.

The results show a significant difference between the withdrawal volumes reported by the companies (WDD) and the estimated collection volumes obtained from the coefficient considering the number of jobs (WEA), according to Figure 4b. It should be noted that during the study, the estimates were obtained through the total number of workers for each company. Comparing the volumes reported with the estimates obtained through the ANA matrix (WEA), the most significant difference was recorded for Usiminas. The collection volume reported by the company in its sustainability report was 50 ML of water, while the estimate based on the number of jobs (WEA) points to 50,457 ML, a volume 1000 times higher (annual production and jobs for 2023). For Suzano, the reported collection (WDD) was 318,248 ML versus 404,994 ML estimated from the number of jobs, a volume 27.26% higher than that reported by the company.

Regarding Suzano, the percentage difference may be related to an error in the total employee count, without considering the specific role of each worker. In the case of Usiminas, it is possible that the discrepancy stems from a combination of factors, such as the specific technological processes used by the company, inaccuracies in recording the number of employees directly involved in production, and the diversity of products it manufactures. One of the hypotheses for such a significant difference could be attributed to the average index use since the factors present significant differences between the lowest and highest technical coefficient used in this study. However, considering the coefficient with the lowest value, the withdrawal volume would be around 1546.28 ML, a volume 30 times higher than that found for the withdrawal reported by the company. Another is the use of reused water in the processes, which can drastically reduce water consumption in the facilities. Vale, for example, collected 496.7 million m^3 of water in Brazil and abroad in 2023, used only 108.9 million m^3 of first-use water in its processes, and returned 344.8 million m^3 unused. However, it used 562.8 million m^3 of reused water, a volume 5.17 times greater than the first-use water.

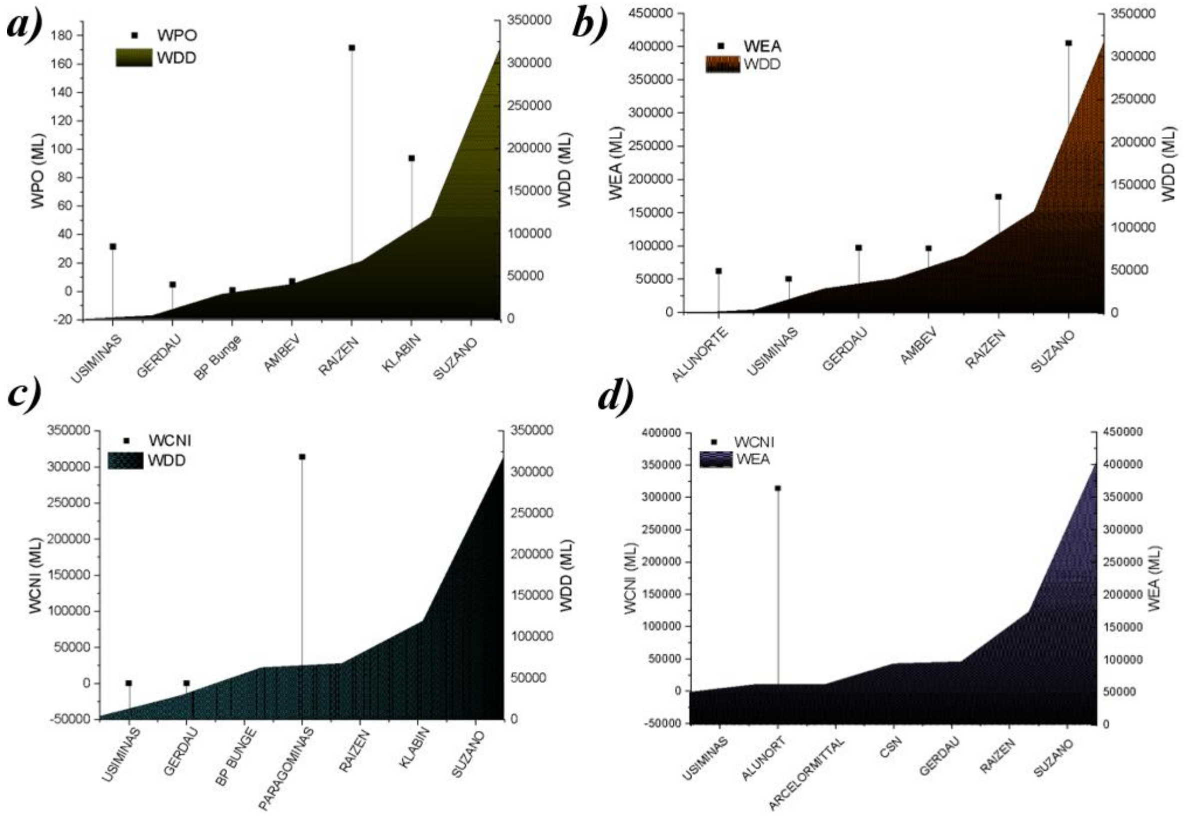

Figure 5. Comparison between withdrawal volumes disclosed by companies (WDD) versus authorization spreadsheet (WPO) of the ANA (a); withdrawal according to the number of jobs in the ANA Coefficient Matrix (WEA) versus WDD (b); withdrawal according to the Technical Coefficient Matrix of the National Confederation of Industry (WCNI) versus DDD (c); withdrawal WCNI versus WEA (d).

The comparison of the estimates obtained from the coefficients based on reported production (WCNI) versus published collection data (WDD) revealed significant discrepancies. As shown in Figure 5c, the collection volumes disclosed by Paragominas and Suzano experienced the most distortion, with reported collection volumes of 602,600 and 318,248 ML, while the WCNI-based estimates indicated collections of 313,912.66 and 2996.8 ML, respectively. If for Paragominas the volume reported was five times higher than the calculated estimate, the collection volume reported by Suzano was 100 times higher than the estimate calculated using the CNI coefficient. Similar results were observed for Gerdau (WCNI of 187.65 and WDD of 4017.40 ML), which presented a difference of around 21 times between them, and for BP Bunge (WCNI of 2422.10 and WDD of 29006.76 ML), whose difference was almost 12 times.

When comparing estimates obtained from the WCNI and WEA (Figure 5d) indexes, significant differences in volumes were observed. The smallest difference was five times the estimated value of WCNI compared to WEA for Alunort (WEA: 62,310.6 ML and WCNI: 313,912.7 ML). However, this difference exceeded 26 thousand times the WEA value compared to the projected WCNI estimate for Raizen (WEA: 173,932.12 ML and WCNI: 66.05 ML). It is important to emphasize that the values obtained by considering annual production

(WCNI) may not reflect the total volume of all products manufactured by the companies studied. Meanwhile, the results based on the number of employees may overestimate collection volumes, as this study considered the total number of employees, not just those working at the manufacturing plant.

When the volumes related to recorded consumption were evaluated, comparisons were made considering the companies that disclosed data regarding annual production (CCNI) and the number of employees (CEA) versus consumption data disclosed by the companies (CPC). It is worth noting that the period evaluated was from 2021 to 2023 and that the data are presented as annual consumption. Among the industries related in Figure 6, those with the greatest divergence in consumption were Raizen and Suzano. Raizen's consumption was estimated by the CEA and CNI at 173,932.12 ML and 95 ML, respectively, while the company's disclosed consumption was 62,670 ML. This was 125,276 ML lower than the CEA estimate and 62,575 ML higher than the CNI prediction. Suzano reported a consumption of 64,000 ML; however, the values estimated by CNI and CEA were 697 ML and 58,643 ML, respectively. The error in the estimate exceeded 5,357 ML for the CEA calculation and surpassed the estimate by 63,304 ML for CNI. We emphasize that the coefficients showing estimated variation were used in the arithmetic mean between factors. Among the results obtained, the smallest divergence was for Usiminas, with the estimate of the CCNI coefficient (40 ML) compared to the volume disclosed by the company (54 ML), presenting an estimate 26.02% lower than the disclosed volume. Conversely, the estimate obtained for the CEA coefficient was higher than the reported volume by 14,743 ML, representing a result for Usiminas 273.87 times higher than the disclosed value.

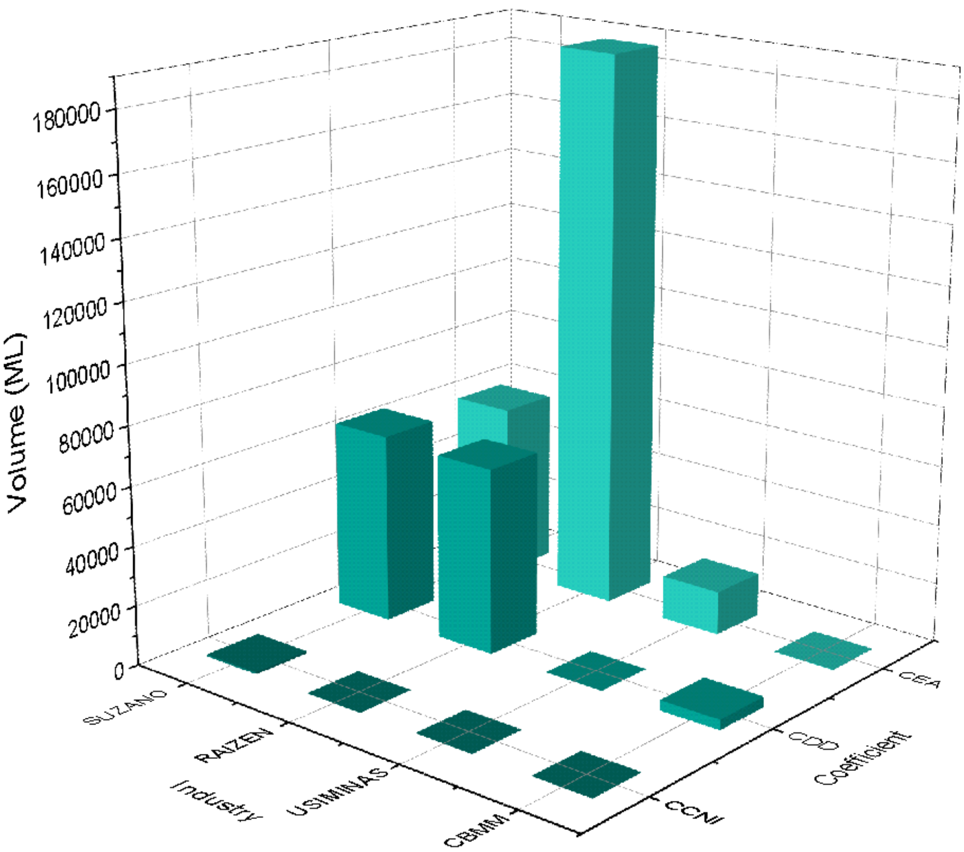

Figure 6. Comparison between the estimated annual consumption volumes according to the Coefficient Matrix of the ANA (CEA), versus the Technical Coefficient Matrix of the National Confederation of Industries (CCNI) based on annual production, versus the consumed volumes disclosed by the companies (CDD) in megaliters (ML).

In the correlation analysis between the discharge disclosed from the Federal Outorgas Worksheets (DPO) versus releases reported by the companies (DDD), extremely significant differences were observed (Figure 7a). Notably, Ambev reported the discharge of 26,053.7 ML of wastewater (DDD), a volume 3,140.6 times greater than that reported through the Federal Outorgas Worksheets (8.3 ML in DPO). For Ambev, the volume reported by the company (26,053.7 ML for DDD) was 2.7 times lower than the volume estimated using the DEA coefficient (71,004.8 ML), as shown in Figure 7b.

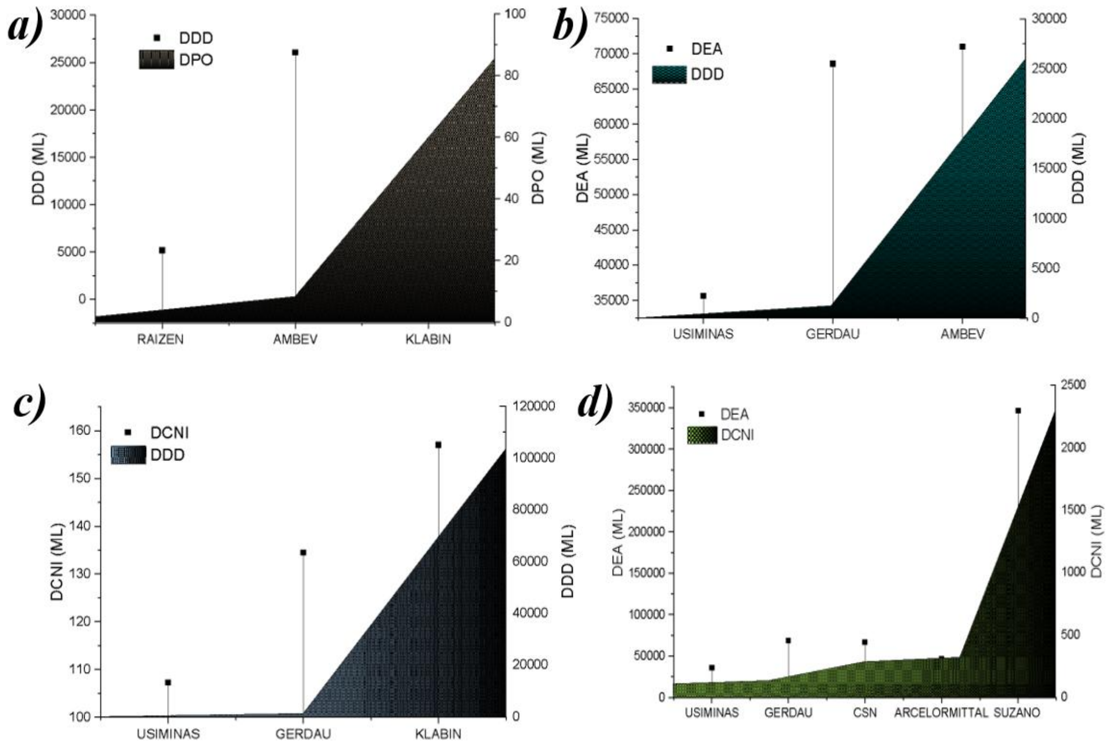

Figure 7. Comparison between discharge volumes disclosed by companies (DDD) versus authorization spreadsheet (DPO) of the ANA **(a)**; discharge according to the number of jobs of the ANA Coefficient Matrix (DEA) versus DDD **(b)**; discharge according to Matriz de Coeficientes Técnicos da Confederação Nacional da Indústria (DCNI) versus DDD **(c)**; discharge DEA versus versus DCNI **(d)**.

When comparing the estimates obtained from the DCNI coefficient versus releases reported by the companies (DDD), the greatest divergence was observed for Usiminas (107,256 ML DCNI), with an estimated volume 963.7 times greater than the volume published by the company (37 ML DDD), as shown in Figure 7c. When comparing the estimates for the DCNI and DEA coefficients, significant differences were observed between them, sometimes greater than one or even more than a hundred times. For Gerdau, for example, the estimated value based on the number of jobs (DEA) indicated a launch of 68,584.31 ML, while the DCNI coefficient indicated an average launch of 134.46 ML. The largest difference was found in the calculated indexes, representing a volume 510.7 times greater than each other. The second largest difference between the estimates was recorded for Usiminas, with a launch of 35,665.985 ML using the DEA coefficient against 107.26 ML obtained with the DCNI coefficient, representing a difference of 332.53 times the latter volume (Figure 7d).

For water withdrawal, consumption, and wastewater discharge, the differences observed in this comparative study are generally extremely significant. These discrepancies may be associated with the lack of specific production data on the products obtained, the wide variety of products manufactured within the same industry, the fact that the coefficients of the CNI matrix do not include all types of manufacturing industries, and the lack of specifications regarding the activities performed by employees in the manufacturing units. These factors combined compromise the establishment of consistent results for the same companies. In addition, for the vast majority of companies, it was not possible to make comparisons since a low percentage of them simultaneously made data regarding the number of employees and production volumes available in digital media.

It was not possible to establish a direct correlation between the data obtained and the estimates for both coefficients, as the variations occurred arbitrarily. Given the observed disparities, it was not possible to determine which index closely approximates the real data disclosed by the companies. Thus, the information available in electronic media regarding Brazilian industries is unreliable for estimating the volumes of water to be withdrawaled, consumed, or discarded in water bodies, considering the coefficients studied.

It can be inferred that the lack of transparency on the part of companies, combined with the difficulty in accessing governmental data, hinders the estimation of water abstraction, consumption, and disposal by the country's main industrial sectors, which may lead to challenges in the management of national water resources.

3.6. Water demand of the country's main industrial sectors (coefficient from scientific literature)

Regarding the annual water demand in Brazil, using coefficients from scientific literature and considering the amount of water needed to produce one kilogram of the evaluated product, an estimated demand of 276,974 mL of water per year was required to meet the manufacturing needs of 22,353 tons of products, including minerals, beverages, proteins, dairy products, leather, paper, pulp, clothing, and petrochemicals (see data in Table 2). It is estimated that the largest volume of water is destined for the beverage industry, which could demand approximately 255,300 mL for the production of 20,424 mL of beverages (volume disclosed in the Etene Sectoral Report (Viana, 2023). In the sector, the demand for water by industries varies according to the types and parameters of processes, the size of the industrial unit, cleaning operations, and the technological apparatus used (Shrivastava *et al.*, 2022). In Brazil, the main beverage producers and distributors are AMBEV, Heineken, and Cervejaria Petrópolis, which hold 56.9%, 15.5%, and 11.8% of the market share, respectively. Diageo, Campari, Cia Muller de Bebidas, and Pitu are also among the 10 largest in the beverage segment (Viana, 2023).

The food industry, involving dairy products and proteins, may require, on average, 426.42 ML of water to produce 55.90 Mt of food. In this segment, the processing that involves the highest water consumption per kg of product is the fish industry, which uses between 10 and 40 ML of water per ton of processed fish (ABP, 2024). For the sector, 17,255.1 ML of water could have been used to process 862.72 Mt of product. Another sector with a significant impact on the water demand of the Brazilian industry is mining, which may have required around 17,340 ML of water to produce 17,000 Mt of minerals in 2021. The water demand for the sector involves between 0.4 and 20 L/kg of minerals produced. The stage with the highest consumption is beneficiation, which in the flotation separation process consumes up to 85% of the total volume (Sampaio *et al.*, 2018). In Brazil, iron ore is the main commodity, standing out because its reserves represent around 20% of world production (Vilaça *et al.*, 2022).

3.7. Data Consolidation

The consolidation of the collected data allows us to observe that, according to the volumes available in the Planilha de Outorgas, licenses were granted for the withdrawal of 741.47 ML and for the discharge of 515.8 ML of water, considering only the companies listed in this study that requested licenses from ANA. According to the data disclosed by the companies, the volumes for withdrawal are 465,733.441 ML and for discharge 136,067.19 ML (considering only the companies that disclosed their usage). Consumption is not included in the Planilha de Outorgas, since these values are not managed by the Agência Nacional de Águas e Saneamento

Básico (ANA) and, therefore, are not used for comparison purposes in this section.

The calculation based on the number of employees (ANA Matrix) allowed us to estimate the total volume withdrawn at approximately 1,056,095.10 ML and the volume discharged at 635,497.91 ML. Using the coefficient from the Confederação Nacional da Indústria (CNI), the total volume withdrawn would be 322,454.96 ML, and the average would be 77,177.88 ML.

Table 2. Volume of water required (ML) per product according to coefficient from scientific literature.

Industries	Annual production (Tons, liters or m^2)	Water volume, ton^{-1}	Demand (ML)	Reference
Dairy	[2]24 millions (2023) Brazil	0.2 a 10 $L_a L_L^{-1}$ process[3]	162.67	[2](Ximenes and Soares, 2024) [3](Qasim and Mane, 2013)
Beef protein industry	[4]10.560 millions (2023)	[4]7.75 L kg^{-1}	81.84	[4](Soares and Ximenes, 2024)
Fishing industry	[5]3.273 thousand (2023)	[7]10 a 40 L kg^{-1}	8.18	[5](Brasil, 2024)
	[6]887029 thousand (2023) [7]115,0974 millions (fillet)	[7]10 a 40 L kg^{-1}	17.74	[6](Associação Brasileira Da Piscicultura, 2024) [7](Giudici *et al.*, 2024)
Poultry protein (chicken, turkey and others)	[8]14.971 millions (2023)	[3]7.75 L kg^{-1}	116.03	[8](Associação Brasileira de Proteína Animal, 2024)
Pork	[8]5.156 millions (2023)	[3]7.75 L kg $^{-1}$	39.96	[8](Associação Brasileira de Proteína Animal, 2024)
Beer and spirits	[9]20424 millions (2021)	[10]10 e 15 $L_v L_b^{-1}$	255300	[9](Viana, 2023) [10](Vymazal, 2014)
Mining	[11]1700 millions (2021)	[12]0.4 a 20 L kg^{-1}	17340	[11](FAPESPA, 2024) [12](Sampaio *et al.*, 2018)
Steel and metallurgy	[13]34.0 (steel) millions (2022)	[14]28.6 L kg^{-1} (aço)	972.4	[13](Viana, 2023) [14](Blanco-Vieites *et al.*, 2022)
Leather (footwear and automotive sector)	[15]91.606 millions m^2	[16]25 a 80 L kg^{-1}	2198	[15](CICB, 2022) [16](Vymazal, 2014)
Clothing and textiles	[17]2.1 millions ton. (2022)	[18]40 L kg^{-1}	84	[17](ABIT, 2024) [18](Behera *et al.*, 2021)
Paper and cellulose	[19]25 millions ton. (2022)	[20]20 a 25 L kg^{-1}	562.5	[19](Portal Celulose, 2023) [20](Sridhar *et al.*, 2011)
Petrochemical industry	[21]20.169 millions ton. (2020)	[22]4.5 L kg^{-1}	90.76	[21](Viana, 2021) [22](Hansen *et al.*, 2018)
Total water demand	22433.962 Mt	294040.5843	294575.1 ML	

On the other hand, for all Brazilian production, as reported by associations and cooperatives in the sector and considering the coefficients from the literature, it was possible to estimate a demand of 276,974 ML of water per year to meet the production of 22,353 ML of minerals, beverages, proteins, dairy products, leather, paper, pulp, clothing, and manufactured petrochemical products.

According to the Agência Nacional de Águas e Saneamento Básico (ANA, 2024), in 2022 alone, 222.14 m^3 s^{-1} of water would be captured, with 190.52 m^3 s^{-1} for the manufacturing industry and 31.62 m^3 s^{-1} for the mineral extraction industry. The manufacturing industry represents 9% of the total water captured in this period. As defined by ANA, there are two types of industries: extractive, which involve the extraction of resources and inputs from nature without altering their characteristics, and manufacturing, which deal with the transformation of raw materials into products, whether final or intermediate. In this work, industries from both the extractive segment, such as Anglo Ferrous, and the manufacturing segment, such as Ambev, were listed.

In the last 12 months, industrial production grew by 1.5% in Brazil, with significant increases in the production of food and automobiles. In the first four months of 2024, production growth reached 3.5% and has been showing progressive growth (IBGE News Agency, 2024). While water production and demand for multiple uses continue to increase progressively, natural water stress in many regions is worsening (CNI, 2024).

Considering that water scarcity can directly affect industrial and agricultural production, have various impacts on the economy, and cause several socioeconomic problems, the sustainable use, rationalization, and allocation of water resources among industries are essential (Ning *et al.*, 2023). Industrial production represents 25.5% of Brazil's (Gross Domestic Product) GDP, generating R$ 2.4169 billion in 2023. The sectors with the greatest impact on GDP include civil construction, oil and natural gas extraction, and metallic mineral extraction, representing 13.8%, 11.6%, and 9.1% of GDP, respectively (Portal da Indústria, 2024).

In this context, transparency regarding the various uses of the country's water resources by economic sectors is important as a planning and management tool for future water sustainability scenarios and for society itself to monitor its consumption. However, it was observed that most of the 30 largest industries in the country, that is, 70% of the companies evaluated in this research, conceal from the public and researchers the volumes of water used in their facilities and discharged into water bodies, with this information being accessible only to government regulatory bodies.

Access to information on water use by the country's main productive sectors is a challenge, since collecting data from companies throughout the national territory depends on access requests to various government agencies, such as environmental secretariats and water supply companies, in addition to consolidating data released by ANA (National Water Agency). Access to this data with uniform characteristics is not always possible, either due to a lack of responses or disparities in response time to this type of request. For this reason, it was decided to use data released both by ANA and by the industries studied themselves, in addition to the coefficients, as described in the methodology.

4. CONCLUSIONS

The study revealed a significant disparity in how each company discloses data on water use at its facilities. Some industries are quite transparent about managing this resource, whether in relation to intake, consumption, or disposal, making this data available in their sustainability reports or websites. However, other companies do not disclose their data to the general public. Another problem identified is the lack of information on the number of employees per country and/or function for most companies, and the disclosure of the total production volume instead of the breakdown of volumes by product manufactured. For the reasons mentioned, the estimates of water volumes withdrawn, consumed, or discharged of, based on the coefficients used in this study, differed significantly from each other and when compared to the volumes disclosed by the companies or by ANA (National Water Agency) through the water rights Planilha de Outorgas. Despite this, the sum of the volumes obtained from data from companies that disclosed their water intake or discharge volumes (465,733.441 and 136,067.19 ML, respectively) was lower than the sum of the intake or discharge volumes obtained from data disclosed through the water use Planilha de Outorgas (741.47 and 515.8 ML, respectively). It was also possible to infer that the smallest discrepancy between the data occurred between these last two. Therefore, estimating water use using technical coefficients can be more effective by accessing data obtained directly from the industry targeted by the study or through government water resource management agencies. However, this can generate other challenges, since obtaining this data may occur in different periods, compromising the correlation of the data and also generating discrepancies. It is also possible to conclude that, for better management of water resources in the country, greater transparency in data disclosure is necessary, both on the part of companies and the government.

5. DATA AVAILABILITY STATEMENT

Data availability not informed.

6. ACKNOWLEDGEMENTS

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SUPPLEMENTARY MATERIAL

Table S1. Water withdrawal permits and discharge permits volumes according to the permit's spreadsheet of the Agência Nacional de Águas e Saneamento Básico (ANA), in megaliters per year (ML year^{-1}).

Name of Applicant	Water withdrawal permits (m^3)									Discharge permits	
	Industrial	Others	Thermoe.	H. Works	H. Cons.	Mining	Irrig. (ML)	Vol. year (ML)	Irrig. (%)	Annual volume (ML)	Disc. (%)
Petrobras Distribuidora S.A.	7093340	73458	13245120	-	-	-	-	20.41192	1.264291	15.31609	2.969356
Vale S.A..	82716	9732448	-	905024.8	302400	6230784	-	17.25337	0.014743	1.931647	0.374492
Cargill Agrícola S.A.	3095200	21132	-	-	168	-	-	3.1165	0.551677	1.577238	0.305782
Bunge Alimentos S.A.	940824	0	-	-	-	-	-	0.940824	0.167689	0.28908	0.056044
Braskem	-	-	-	-	-	-	-	-	-	-	-
Shell Brasil	-	-	-	-	-	-	-	-	-	-	-
Arcelormittal Sul Fluminense s.a.	6425280	-	-	-	-	-	-	6.42528	1.145219	0.649412	0.125903
Refmat		-	-	-	-	-	-		0		
Seara Alimentos LTDA	4555200	-	-	-	-	-	-	4.5552	0.811902	3.52464	0.683328
Brf S.A.	38868200	-	-	-	-	-	-	38.8682	6.927728	-	-
Louis Dreyfus Company Sucos S.A.	0	226560	-	-	-	-	21134248	21.36081	0	0.007131	0.001383
Ambev S.A.	7017600	-	-	-	-	-	-	7.0176	1.250792	8.295792	1.608319
Suzano Papel e Celulose	-	-	-	-	-	-	2365.2	0.002365	-	-	-
Yara Alimentos Eireli	-	-	-	-	-	-	-	-	-	0.042048	0.008152
Usinas Siderurgicas de Minas Gerais s/a. Usiminas	31536000	-	-	-	-	-	-	31.536	5.620863	-	-
Companhia Siderúrgica Nacional (CSN)	3.14E+08	-	-	-	-	-	-	313.8007	55.93071	123.9559	24.03154
Basf S.A.	5658960	-	-	-	-	-	584024	6.242984	1.008633	3.69672	0.716689
Alunorte Alumina do Norte do Brasil S.A.	-	-	-	-	-	-	-	-	-	269.316	52.21273
Spal Indústria Brasileira de Bebidas S.A.	-	-	-	-	-	-	-	-	-	0.025459	0.004936
Gerdau S.A.	4619784	-	-	-	-	-	-	4.619784	0.823414	-	-
Klabin S.A..	93819600	-	-	-	-	-	-	93.8196	16.72207	85.56768	16.58914

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Petrogal brasil	-	-	-	-	-	-	-	-	-	-	-
Spal (coca-cola femsa)	-	-	-	-	-	-	-	-	-	-	-
Minerva foods	-	-	-	-	-	-	-	-	-	-	-
Raizen energia S.A.	43539220	19353.6	-	-	-	-	1.28E+08	171.5019	7.760274	1.6104	0.312211
Anglo Ferrous	-	-	-	-	-	-	-	-	-	-	-
CBMM	-	-	-	-	-	-	-	-	-	-	-
Total	5.61E+08	10072952	13245120	905024.8	302568	6230784	1.5E+08	741.473	100	515.8053	100

* Thermoe.: Thermoelectric; H. Works: Hydraulic Works; H. Cons.: Human consumption; Irrig.: Irrigation; Disch.: Discharge.

Table S2. List of companies evaluated with the respective items produced, net revenue and estimated water consumption and disposal calculated using the coefficients of the " Matriz de Coeficientes Técnicos da Agência Nacional de Águas (ANA)" based on the technical document of the "Division of the National Classification of Economic Activities (CNAE 2.0)" considering the number of jobs disclosed by the companies.

Cia	Sector	Products	Net revenue (R$)	Division	Group	Class	Number of employees	Year	Annual withdrawal /364 day (ML)	Consumo anual/364 dias (ML)	Source
Petrobras e Petrobrás Biocombústiveis S.A.	Chemistry and petrochemistry	Diesel, gasoline, aviation kerosene, cooking gas and many other products	6.13E+08	19	192	19217	40213	2023	220.3095	44.52737	(Petrobras, 2024)
Vale S.A.	Mining, cement and petroleum,	Iron ore, pellets and nickel, manganese, ferroalloys, copper, gold, silver and cobalt	1.42E+08	NCC	-	-	55247	2023	-	-	(Vale, 2024)

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Cargill Agrícola S.A.	Food and beverage	Food products for human and animal consumption	94123597	NA	-	-	11000	2023	-	-	(Garcill, 2024)
Bunge e BP Bunge	Food, beverage and biofuels	Processing of grains and oil seeds, wheat flour, oils, fats and proteins	78561058	NA	-	-	17000	2023	-	-	(BP Bunge Bioenergia, 2023)
Braskem	Chemistry and petrochemistry	Polyethylene, polypropylene and polyvinyl chloride resins, ethylene, propylene, butadiene, benzene, toluene, chlorine, soda and solvents, among others	68091006	20	203	20312 (termoplásticos)	6419	2023	9.378775	5.782877	(Braskem, 2024)
Shell Brasil	Oil and gas	Oil	60410000	NCC	-	-	900	2023	-	-	(Shell, 2024)
Shell Brasil	Mining, metallurgy and steel industry	Produces high quality long and flat steel for the automotive, home appliance, packaging, civil construction and shipbuilding industries	57313493	24	111 a112	-	17215	2022	62364.95	16088.62	(ArcelorMittal Brasil, 2023)

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REFMAT	Chemistry and petrochemistry	Associated with Petrobras	57228164	NA	-	-	-	-			-
JBS (Seara, JBS couros, Friboi)	Food, beverages and leather	The portfolio in the country is diversified, with operations in the segments of beef, chicken, pork, fish, plant-based, prepared and frozen foods, biofuels and leather	54942851	NA	-	-	143879	2022			(JBS, 2023)
BRF	Food and Beverages	Fresh, frozen and processed poultry and beef protein	46630860	NA	-	-	89992	2023			(BRF S. A., 2023)
Louis Dreyfus BR	Food and Beverages	Coffee, cotton, grains, juice, oilseeds, rice and sugar	45507809	NA	-	-	11000	-			(Louis Dreyfus Company BR, 2024)
AMBEV	Food and Beverages	Produces beers and non-alcoholic beverages	38494443	11	111 a 112	-	29239	2022	96382.97	25378.22	(Ambev, 2024)
Suzano	Paper and pulp	Paper and pulp	30755701	17	171 a 174	-	20627	2023	404993.8	58643.01	(Suzano, 2023)

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Yara Brasil	Chemistry and Petrochemistry	Coagulant, civil explosives, drilling fluid, concrete accelerator admixture, nitrogen chemicals	29780716	NA	-	-	5302	2023			(Yara, 2023)
Usiminas	Metallurgy and Steel Industry	Coated steels, mainly for the automotive, home appliance and construction industries	28688733	24	242 a 243	-	13928	2023	50457.1	14791.12	(Usiminas, 2023)
Companhia Siderurgica Nacional (CSN)	Metallurgy and Steel Industry	Iron ore, flat steel, coated steel, galvanized steel, pre-painted steel, metal sheets and long steel (rebar and wire rod)	24214687	24	241 a 243	-	26053	2023	94382.46	27667.5	(CSN, 2024)
BASF	Chemistry and Petrochemistry	Raw materials for highly demanding paints and coating applications such as architectural and automotive	24044691	NA	-	-	4 456	2023			(Basf, 2024)

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Gerdau Cosigua	Metallurgy and Steel Industry	Aços planos, além de minério de ferro para consumo próprio.	19815427	24	241 a 243	-	26783	2022	97027.04	28442.74	(Gerdau, 2023)
Klabin	Paper and cellulose	Papers and cards	19719660	17	171 a 174	-	GDD	2022	-	-	-
Petrogal Brasil	Produção e exploração de petróleo	Oil and natural gas	17718531	NA	-	-	101	2022	-	-	(Galp, 2023)
Gerdau Acominas	Metallurgy and Steel Industry	Steel	17212111	NA	-	-	26783	2022	-	-	(Gerdau, 2023)
SPAL (Coca-Cola FEMSA)	Food and Beverages	Soft drinks, water, teas, nectars, juices, dairy products, coconut water, sports drinks and plant-based drinks	16884043	-	-	-	21 281	-	-	-	(Coca-Cola FEMSA Brasil, 2023)
Minerva Foods	Food and Beverages	Fresh meat and its derivatives, export of live cattle, in addition to also working in the processing of beef, pork and poultry	15780981	NA	-	-	12 937	2023	-	-	(Minerva S.A., 2024)
Raizen Energia	Sugar and alcohol industry	Sugar and Alcohol	14066812	10 ou 19	107 ou 193	-	26783	2022	173932.1	173932.1	(Raizen, 2024)
CSN Mineração	Mining, cement and oil	Mining, cement and oil	13258159	NA	-	-	26053	2023	-	-	(CSN, 2024)
Continue...											

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CSP (Arcelormittal)	Metallurgy and Steel Industry	High quality steel plates	12392433	24	241 a 243	-	17200	2022	62310.61	18265.88	(ArcelorMittal Brasil, 2023)
CSP (Arcelormittal)	Mining, cement and oil	Iron and manganese ore; metallurgical coal and mineral coal; base metals and minerals – copper, nickel, niobium and phosphates; and precious metals and minerals	11266905	NA	-	-	GDD	-	-	-	-
Alunorte	Metallurgy and Steel Industry	Alumina refinery	11248435	24	244	24491	2200	2023	1029.829	205.8056	(Hydro Alunorte, 2024)
CBMM	Metallurgy and Steel Industry	Niobium Products	10953751	24	244	24491	1926	-	901.5683	180.1734	(CBMM), 2023)
REPSOL	Oil and gas production	Oil and gas exploration and production	10806621	NCC	-	-	104	2023	-	-	(Grupo Repsol, 2024)

* **Source:** adapted from https://publicacoes.estadao.com.br/empresasmais/ranking-1500

Table S3. Technical coefficients of the " Matriz de Coeficientes Técnicos da Agência Nacional de Águas (ANA)" based on the classification of activities of the document "Divisão da Classificação Nacional de Atividades Econômicas (CNAE 2.0) " according to the activities listed in this work.

Division	Group	Grade	Withdrawal coefficient	Consumption coefficient
			Liters (employees.day^{-1})$^{-1}$	
10 - Manufacture of food products	107- Sugar manufacturing and refining	-	16490	16490
11- Beverage manufacturing	111 -Manufacture of alcoholic beverages	-	5414 a 13330	1048 a 2813
	112 -Manufacture of non-alcoholic beverages	-	4782	1956
17 -Manufacture of pulp, paper and paper products	171 -Manufacture of cellulose and other pulps for papermaking	-	107683	16665
	174 -Manufacture of various paper, cardboard, cardstock and corrugated cardboard products	17419 a 17494	197 a 6000	63 a 1923
19 -Manufacture of coke, petroleum products and biofuels	192 -Manufacture of petroleum products	19217 -Manufacture of petroleum refining products	15051	3042
	193 -Biofuel manufacturing	-	19192	19192
20 -Chemical manufacturing	203 -Manufacture of resins and elastomers	20312 -Manufacture of thermoplastics	4014	2475
24 -Metallurgy	241 -Production of pig iron and ferroalloys	24113 a 24121	3034 a 5708	660 a 1241
	242 -Steel industry	24211 a 24245	1477 a 19600	
	243 -Production of steel pipes, except seamless pipes	24318 a 24393	305 a 885	61 a 177
	244 -Non-ferrous metallurgy	24491 -Metallurgy of non-ferrous metals and their alloys not elsewhere specified	4849	970

Table S4. Technical coefficients of the "Matriz de Coeficientes Técnicos da Confederação Nacional da Indústria (CNI)" based on the classification of activities of the document "Divisão da Classificação Nacional de Atividades Econômicas (CNAE 2.0)" according to the activities listed in this work.

Division	Group	Grade	Withdrawal coefficient	Consumption coefficient	Discharge coefficient
				L ton^{-1}	
7 - Extraction of metallic minerals	7.1 - Iron ore extraction	-	1.05	0.18 – 1.00	0.87
	7.2 - Extraction of non-ferrous metallic minerals	07.21-9 -Aluminum ore extraction	3.42	2.91	0.5
	-	07.29-4 -Extraction of non-ferrous metallic minerals not otherwise specified	1.86	1.58	0.28
8 - Extraction of non-metallic minerals	8.9 - Extraction of other non-metallic minerals	08.91-6 - Extraction of minerals for the manufacture of fertilizers and other chemical products	16.4 a 47.5	6.6 a 13.8	2.6 – 36.8
10 -Manufacture of food products	10.1 -Slaughter and manufacture of meat products	10.11-2 -Slaughter of cattle, except pigs	2	0.25	1.75
		10.12-1 -Slaughter of pigs, poultry and other small animals	4.0 a 12.00	0.5 a 1.5	3.5 a 10.5
	10.7 -Sugar manufacturing and refining	-	17	17	-
11 -Beverage manufacturing	11.1 -Manufacture of alcoholic beverages	11.11-9 a 11.13-5	4.0 a 5.4	0.8 a 1.2	3.2 a 4.3
	11.2 - Manufacture of non-alcoholic beverages		1.4 a 3.0	0.9	0.5 a 2.1
15 -Preparation of leather and manufacture of leather goods, travel goods and footwear	15.1 -Tanning and other leather preparations	-	0.47 a 1.00	-	0.47 a 1.00
17 -Manufacture of pulp, paper and paper products	17.1 -Manufacture of cellulose and other pulps for papermaking	-	25.9 a 46.8	3.2 a 5.8	22.7 a 41
	17.2 -Manufacture of paper, cardboard and paperboard		10 a 46.3	1.8 a 8.4	8.2 a 37.9
19 -Manufacture of coke, petroleum products and biofuels	19.3 -Biofuel manufacturing	-	2	2	-
20 -Chemical manufacturing	20.3 -Manufacture of resins and elastomers	-	2.0 a 15	1 a 4	1 a 11
23 -Manufacture of non-metallic mineral products	23.2 -Cement manufacturing	-	0.08 a 0.4	0.08 a 0.5	-
24 -Metallurgy	24.2 -Steel industry		33.6	8.7	24.9
	24.4 -Metallurgy of non-ferrous metals		1.24 a 3.5	0.25 a 0.7	0.99 a 2.8