Exploring Fallacies and Environmental Responsibilities in the Socio-Environmental Reports of the Brazilian Company Vale S.A.: A Case Study on the Dam Disasters in Mariana and Brumadinho

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Abstract

The objective of this study was to analyze the level of fallacies present in the socio-environmental reports of Vale S.A., the third-largest mining company in the world, with a focus on the incidents in Mariana (2015) and Brumadinho (2019) in Brazil. We also examined the potential relationship between socio-environmental investments, fallacies, and environmental liabilities during the period of 2010-2022. Fallacies of appeal to motives were extracted from sustainability reports using NVivo®. Data on socio-environmental investments, environmental liabilities, and company disclosures were obtained from Economatica®. Non-parametric statistical analysis using Stata® revealed that socio-environmental investment trends suggested a reduction in environmental liabilities and contingencies. However, this relationship lacked statistical significance. The variable "accident" showed a significant association with investments ($p<0.02$), indicating a connection between accidents and the company's investments, impacting environmental liabilities except those related to pre-disaster events. Notably, the company implemented changes in the dam model only after the second accident in 2019, approximately four years after the initial incident. This aligns with the fallacy of appeal to motives, showing a positive and statistically significant association, suggesting an increase in this fallacy after the accidents. In summary, this research analyzed fallacies in the socio-environmental reports of Vale S.A. in the context of the dam failures in Mariana and Brumadinho. It explored the relationship between socio-environmental investments, fallacies, and environmental liabilities, revealing a significant link between accidents and the persistence of certain fallacies despite serious environmental incidents.

Keywords: socioenvironmental investment, environmental liability, contingent liability, appeal to motives fallacy, environmental accident

1. Introduction

1.1 Sustainability Report

With the adoption of the "Environment, Social, and Governance (ESG)" symbolism by companies, measuring the actual implementation of genuinely sustainable practices for the environment becomes challenging.

This situation leaves investors reliant on communications that hinge on a specific 'materiality' for the disclosure of company actions, given the non-obligatory nature of Sustainability Reports or Integrated Reports (Abhayawansa & Tyagi, 2021).

With the issuance of the General Requirements for Disclosure of Sustainability-Related Financial Information (IFRS S1), approved in June 2023 by the International Sustainability Standards Board (ISSB), it is anticipated that there will be standardization of the topics covered in socio-environmental disclosure and increased clarity regarding materiality.

However, until the effective implementation of S1, some companies may resort to what the authors term as fallacious arguments in socio-environmental disclosure. This situation poses a constant challenge in the pursuit of improvement in Corporate Sustainability Reports, as many employ robustness and greenwashing to deceive stakeholders (Kurpierz & Smith, 2020).

Nevertheless, not only are green lies included in the reports, but also the use of fallacies, which are arguments that appear true but are crafted to divert the information recipient's attention towards the positive aspect while sometimes omitting data that could potentially harm the company's image (Arp et al., 2019).

An example of the poor quality of information reported in the reports was noted by Rashidfarokhi et al. (2018) when they found that sustainable disclosures were inconsistent, lacked clarity in materiality metrics, or did not resort to external guarantees for validation, thus employing shallow explanation fallacies. Gazzola et al. (2021) identified the selection of information depending on the amount of funding that would be offered to Non-Governmental Organizations (NGOs) in Italy. The greater the resources to be received, the greater the socio-environmental reporting by NGOs; in this case, the fallacy of the cause taken by the effect was used.

1.2 Appeal to Motives Fallacies

But what is a fallacy, and how can it be identified? Carnielli and Epstein (2019) delineate three essential points for identifying a fallacy: (i) fallacies are errors in reasoning and not factual errors (i.e., something real); (ii) they need to be applied in an argument (i.e., in context); (iii) they need to be deceptive. Hamblin (1970) also emphasizes that fallacies can be constructed from true statements, even if the arguments are vacuous.

According to Downes (1995), the primary informal fallacies are categorized into 12 types: dispersion; appeal to motives; red herring; inductive; definition errors; general rules; causative; target failure; ambiguity; category errors; non sequitur; and explanation errors. The definition of each of them is presented below:

• Ambiguity: pertains to the lack of clarity in a sentence or word.

• Appeal to Motives: employs strategies that make use of psychological elements.

• Causal: justifies one fact because of another.

• Dispersion: involves false maneuvers for diverting attention.

• Category Errors: results from the sender's misunderstanding.

• Definition Errors: lack premises to support the conclusion.

• Explanation: occurs when the sender responds to a question with another question or when there is no theoretical or scientific basis for the argument's conclusion.

• Target Failure: cannot prove the truth of the defended conclusion.

• Red Herring: employs extremely disconnected reasons from the topic.

• Inductive: fails to conclude the raised topic coherently.

• Non Sequitur: points out errors that do not follow from a valid sequence.

• General Rules: relies on exceptions that generally do not occur.

It is evident that these twelve categories are rhetorical strategies aimed at diverting or not explaining something that has been questioned. However, the appeal to motives fallacy, the focus of this article, aims to emotionally sway the reader or listener with false arguments or even appeals to other means to convince others of their truth.

According to Walton (1980), the category of Appeal to Motives comprises five types: appeal to force; appeal to consequences; appeal to prejudice or emotion; appeal to pity; and appeal to the people.

The appeal to force fallacy is defined by Damer (2009) as a tactic that seeks to persuade others of a truth based on the threat of undesirable outcomes if the other party does not agree. This occurs when the speaker lacks premises to support their version, rendering the argument irrelevant.

On the other hand, the appeal to consequences fallacy is defined by Arp et al. (2019) as passages that indicate possible consequences that may arise from not accepting the truth imposed by the speaker, triggering a series of events. The authors also mention that to identify it, one should look for conclusions that are generally pragmatic rather than fact-based. The appeal to force fallacy is often confused with the appeal to consequences, but in the latter, there is no threat to the listener; there is only pressure that if they do not accept the other person's opinion, something will happen.

In the appeal to emotion or prejudice, Allen (2017) mentions that these types of fallacies are expressions that purely rely on pre-judgment of something without reason; instead, they are based on emotions and are used to influence the decision-making of others. The author also highlights that this type of fallacy is frequently used in advertising media to evoke emotions in potential consumers.

A similar fallacy is the appeal to pity (*argumentum ad misericordiam*). In this fallacy, the speaker attaches their

own feelings to affect the listener, diverting attention from what really matters and appealing to pity to gain acceptance of their reasons, which would not be accepted in other circumstances (Tindale, 2007).

In the appeal to the people fallacy (*argumentum ad populum*), Almossawi (2017) notes that passages are recognized for attempting to prove something as true without concrete evidence. Furthermore, the author emphasizes that this type of appeal relies on common sense strategies, meaning it depends on popular knowledge, what is known by everyone, what is trendy, or what is expected from government or corporate actions.

An example of the appeal to the people fallacy is found in the research of Zakrison et al. (2015), where a mining company claimed that sustainable development could be derived from its activities. However, this claim was refuted through focus group discussions with employees, who identified real health impacts from their functions and observed environmental damage in El Salvador resulting from the company's activities.

1.3 Case Study and Tailings Dams

Based on its market value, Vale S.A. is considered the third-largest mining company in the world. The company was originally founded in 1942 as a state-owned entity but is now a private multinational corporation with operations in over 20 countries. In the last year, it reported a consolidated net profit of nearly US$ 18.4 billion and distributed approximately US$ 0.41 per share in dividends and interest for 2022 (Vale S. A., 2023a).

The company produces various types of minerals, but the majority of its revenue comes from iron ore, which reached approximately 308 million tons produced in 2022 (Vale S. A., 2023b). However, iron ore and other minerals require beneficiation to extract valuable ore, and this process generates mineral waste that is stored in tailings dams (Hancock, 2021).

According to the National Mining Agency (ANM), mineral tailings dams can be classified based on construction methods, which include upstream raising, downstream raising, centerline raising, and upstream raising (National Mining Agency [ANM], 2023a).

The upstream raising construction method, as classified by Soares (2010), is the oldest, has the lowest cost, and is more prone to instability because it involves constructing dams that settle along the edge of the reservoir. Azam and Li (2010) add that upstream tailings dams are embankments of byproducts placed with slopes and that, despite having drainage devices, there is a possibility of liquefaction of the tailings. Cardozo et al. (2017) point out that the upstream method is more prone to failures due to its complex supervision and low resistance to seismic activity. They recommend the downstream construction method, despite its higher implementation and operational costs, as this dam model can accommodate any type of tailings, is resistant to earthquakes, and is suitable for water retention.

Today, there are sustainable models for the utilization of these mineral residues, often incorporated in the construction industry, as well as projects aimed at more effective control of dams, including pre-analysis systems for movements, among others (Dong et al., 2020). The fact is that tailings stored using the upstream construction method still pose a potential danger to surrounding communities, as they can lead to contamination of the groundwater, affect rivers or lakes, and cause other environmental impacts in the event of a breach (Kossoff et al., 2014).

A longitudinal study conducted by Azam and Li (2010) examined 100 years of accidents related to mineral waste dams, totaling 218 events up to 2010. The main identified causes were weather conditions and poor operational management of the dams. These factors corroborate the research by Rico et al. (2008), who identified 145 dam breaches in Europe until 2006, with 47% of these incidents involving upstream dams.

Tailings dams have been a long-standing socio-environmental issue in Brazil. According to Ávila et al. (2021), leaks or breaches began with the Cauê Mine in the municipality of Itabirito, Minas Gerais, in 1960, followed by the Rio das Ostras Dam incident in the state of Rio de Janeiro in 1974. Other accidents occurred at dams in Minas Gerais, including Cataguases (1983), Fernandinho (1986), Rio Verde (2001), Florestal Cataguases (2003), São Francisco (2006/2007), Santana do Deserto (2007), and Herculano (2014), some of which resulted in fatalities and serious social and environmental damage.

However, the first major disaster of note was the Fundão Dam owned by Samarco Mineradora, a joint venture between Vale S.A. and BHP Billiton, with both companies holding 50% of the share ownership (Samarco, 2023). This accident caused significant environmental and social impacts in the region. According to Andrade (2023), there was an increase in thefts in the city of Mariana due to the large number of people in shelters without means of subsistence, as 41 cities were affected, and 19 people lost their lives. This incident was different from the one in Brumadinho, which resulted in the deaths of nearly 300 people, mostly company employees.

Why have there been so many dam accidents in recent years? Armstrong et al. (2019) assessed the possible factors contributing to failures in the Mount Polley dam in Canada (2014), Los Frailes dam in Spain (1998), Fundão dam (2015), and Feijão dam (2019) in Brazil. They found that in most cases, failures were due to increased production driven by bonuses awarded to managers, as well as cost reductions and a lack of experienced personnel. It is necessary for companies to share responsibility with the environment, and stricter laws and more rigorous oversight by authorities granting mineral exploitation rights are essential.

In Brazil, following the Brumadinho incident in 2019, the National Mining Agency (ANM) submitted a proposal to amend the National Dam Safety Policy (PNSB), which became Law n. 14,066/2020. Article 2° of this law prohibits the construction or raising of dams using the upstream construction method, as it involves building embankments on the tailings or sediment themselves (Brazil, 2020).

However, there are still 61 dams with upstream construction in Brazilian territory, and 10 of these are in an alert status. In total, Brazil has 928 dams, with the majority located in the state of Minas Gerais. Among them, 266 dams are classified as having a High Associated Damage Potential (DPA), with 73 of these belonging to Vale S.A. (ANM, 2023b).

Following the Brumadinho incident, the company recognized a provision in its liabilities to decommissioning upstream construction dams, with an initial value of over US$ 1.4 billion, aiming to modify 9 dams within three years (Vale S.A., 2019). In the latest integrated report published by the company, there has been progress toward this goal, with 12 dams fully decommissioned and 18 remaining to be completed by 2035 (Vale S.A., 2023c).

1.4 Investments, Contingent Liabilities, and Environmental Liabilities

According to Bertoli and Ribeiro (2006), environmental liabilities arise from negative externalities caused by a company, involving expenses related to recovery, preservation, and/or protection, as well as fines resulting from environmental damage to wildlife and flora. Kennedy et al. (1998) point out that companies face significant challenges in estimating such environmental liabilities, especially in the early stages of remediation, as they depend on various factors, including the financial feasibility of other parties involved.

Such uncertainties and risks can result in losses or gains for companies, driving the recording of contingencies. Therefore, it is important to provide adequate disclosure in financial reports to accurately represent the reality to their users (Costa et al., 2017). Thus, regulatory bodies have issued standards to regulate the disclosure of contingent liabilities. A contingent liability is understood as "a possible obligation that arises from past events and whose existence will be confirmed only by the occurrence or non-occurrence of one or more uncertain future events that are not entirely within the control of the entity" (Accounting Pronouncements Committee [CPC], 2009).

In the current scenario, companies have faced significant pressure to accurately disclose their business activities, particularly regarding the impacts of their social, financial, and environmental actions (Cunha & Ribeiro, 2016). According to Salgado et al. (2012), international literature has focused on presenting the benefits of incorporating socio-environmental investments into corporate practices. Among the results are profit maximization, improved managerial processes, enhanced corporate image, and stakeholder trust.

1.5 Problem and Objective

Socio-environmental communication is a matter of public interest and has been the subject of research by various authors over the years, including Abhayawansa and Tyagi (2021), Baviera-Puig et al. (2015), Christofi et al. (2012), and Muslu et al. (2019). Most of these studies assess the quality of information, whether qualitative or quantitative, with the aim of improving this important instrument of corporate reporting. However, it is worth noting that such reporting is not mandatory for all companies, which can lead to potential gaps in its content.

In an effort to contribute to the improvement of socio-environmental disclosure, this article focuses on the sustainability reports of Vale S.A., as they serve as a communication tool through which the company can provide information to stakeholders and offer justifications for the damage caused in the cities of Brumadinho and Mariana. Based on the Theory of Fallacies, it is expected that the company may use persuasive discourse to mitigate its culpability through these reports.

Given the context of the lack of standardization in corporate sustainability discourse and the potential use of fallacies for information management with stakeholders, this article aimed to answer the following research question: "What is the level of persuasive fallacies in the socio-environmental reports of Vale S.A., considering the incidents in Mariana (2015) and Brumadinho (2019) in Brazil?"

Therefore, the objective of this study was to analyze the potential increase in persuasive fallacies in the

socio-environmental reports of Vale S.A., focusing on the accidents that occurred in the cities of Mariana and Brumadinho in the state of Minas Gerais, Brazil. To expand the research, we also examined the potential relationship between the identified fallacies and socio-environmental investments, environmental provisions, contingent or non-contingent environmental liabilities during the period from 2010 to 2022, considering the administrative focus of Prospect Theory, as possible losses are important for companies (Edwards, 1996).

Furthermore, as we focused on the environmental disasters caused by the rupture of the Fundão (2015) and Feijão (2019) Dams, we created two dummy variables for statistical tests: the variable "Accidents" ('accid') and "Law" ('law'). This "Law" variable represents the prohibition of the upstream dam type, which was the method adopted by the dams under study. Thus, this research aims to support the findings of Liao and Shi (2018), who identified a positive relationship between appeals and the publication of sustainable policies.

2. Method

The methodology employed in this research is of an inductive nature, involving both qualitative and quantitative analysis.

2.1 Qualitative Analysis

To achieve the research objective, sustainability reports and integrated reports from Vale S.A. were collected from the company's ESG portal, starting from its first publication in 2006 up to 2022. The content analysis began by using Walton's Pragmatic Theory of Fallacies (1995) to identify fallacies of appeal to motives. All materials were read, and instances of fallacious appeals were identified and categorized. Subsequently, the NVivo® software, version 1.7.1, provided by the University of Brasília (UnB) free of charge, was utilized to analyze this qualitative data. This software allowed for the identification of fallacies before and after the accidents in Brumadinho and Mariana, as well as the identification of the most prominent types of fallacies.

2.2 Quantitative Analysis

In the second phase of the research, explanatory notes from the mining company were collected using the Economatica® software, also provided free of charge by UnB. This involved extracting all financial statements of the company. By analyzing the balance sheets, it was possible to identify provisions related to the Brumadinho accident in the consolidated liabilities. However, the financial statements did not clearly classify environmental liabilities, assets, or expenses. Therefore, explanatory notes were consulted.

Explanatory notes were only available from 2010 onwards, limiting the research period. Nevertheless, they provided information about the following environmental liabilities: deposits in lawsuits, provisions for lawsuits, compensation provisions related to Samarco, Brumadinho compensation provisions, and provisions for the costs of altering the dam model from upstream to other methods permitted by the new legislation.

It is worth noting that, based on explanatory notes, it was possible to identify contingent environmental liabilities, which, as per International Accounting Standards (IAS) 37 governing Provisions, Contingent Liabilities, and Contingent Assets, do not need to be recorded on the balance sheet unless a probable loss is anticipated. However, Santos et al. (2021) emphasize that contingent liabilities can negatively influence a company, given the unassumed risk of possible future losses, based on Prospect Theory.

The variable of socio-environmental investments was identified in the sustainability reports. By combining these data with the 'Accident' dummy variable and the exogenous variable 'Law,' the study variables are presented in Table 1, as informed by previous literature.

Table 1. Study variables

Variables	Abbreviation	Source	Theoretical Basis
Appeal Fallacy	appeal_fall	Sustainability report	(Walton, 1997; 2012)
Socio-environmental Investment	socioenv_inv	Sustainability report	(Liao & Shi, 2018)
Environmental Judicial Deposits	env_jud_dep	Explanatory notes	(Höck et al., 2020)
Provision of Environmental Processes	prov_env_proc	Explanatory notes	(Höck et al., 2020)
Samarco Provision	samarco_prov	Explanatory notes	(Höck et al., 2020)
Provision for Decharacterization Dams	prov_dec_dams	Economatica®	(Höck et al., 2020)
Brumadinho Provision	brumar_prov	Economatica®	(Höck et al., 2020)
Environmental Contingent Liabilities	env_cont_liab	Explanatory notes	(Paananen et al., 2021)
Accident	accid	Sustainability report	(Fogaça et al., 2023)
Amendment of the Law n. 14,066/2020	law	Federal government	(Liao & Shi, 2018)

Note. The variable for appeal fallacies was extracted from the NVivo® content analysis quantitative.

2.3 Research Hypotheses

For the quantitative analysis, Stata® version 16 was used. The analysis began with the Shapiro-Wilk normality test, which is suitable for smaller samples; in this case, a sample spanned 13 years. The test results indicated non-normalized data, so non-parametric tests were employed for the analysis of the variables (Note 1).

Next, the main hypothesis of this research was examined, based on the Wilcoxon test. This test requires paired data, so 5 years before the first accident and 5 years after were selected, restricting the observation period from 2010 to 2019. It is important to note that the 2019 report mentioned the Brumadinho accident since it occurred on January 25th, and the report was only published in May 2020. Research Hypothesis 1 aims to corroborate the findings of the qualitative research and answer the research question.

Hypothesis 1:

H0 - There is equality in the level of fallacious appeals after the studied environmental accidents.

H1 - There is no equality in the level of fallacious appeals after the studied environmental accidents.

This hypothesis is supported by Walton's Theory of Fallacies (1994), which aims to use unfounded arguments to persuade or deceive the reader. Thus, it is expected that in the years of accidents, the level of fallacies will be higher to mitigate stakeholder concerns.

Given the non-normality of the data, the Spearman correlation was used to check for a statistically significant relationship between socio-environmental investments and environmental liabilities. This hypothesis is based on the research by Liao and Shi (2018), who found that higher environmental investments are associated with a willingness to reduce liabilities. Our research expects that the impact of investment will also be observed in contingent environmental liabilities. Thus, hypothesis 2 was formulated:

Hypothesis 2:

H0 - There is a negative relationship between socio-environmental investment and environmental liabilities.

H1 - There is no negative relationship between socio-environmental investment and environmental liabilities.

3. Results

3.1 Qualitative Analysis

The first phase of the research involved reading the reports and then subjecting them to analysis in Nvivo®. After this, the types of fallacies belonging to the category of Appeals to Emotions were coded in the system, including appeals to force, pity, people, prejudice or emotion, and consequences.

During the reading of the reports, phrases that fit into these appeals were identified (Note 2). Here's an example from the 2019 report: "Vale apologizes to society and deeply regrets the 270 fatal victims, including two young pregnant women, and 11 victims have not yet been located" (Vale S. A., 2019, p. 14).

This sentence uses the appeal to pity, requesting that the public understand that the company comprehends the extent of the tragedy that occurred in Brumadinho. However, research like that of Ragazzi and Rocha (2019) reports that there were indications of the company's knowledge of possible structural flaws in the Feijão Dam before the incident.

In the content analysis, the total of each category of fallacies presented was extracted, as shown in Table 2, totaling 290 fallacious appeals.

Table 2. Types of appealing fallacies identified in reports

Fallacies/Years	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	TOTAL
Appeal to the people	7	14	7	10	10	8	6	24	16	26	15	33	18	194
Appeal to prejudice or emotion	4	5	3	-	2	3	1	-	3	9	1	11	6	48
Appeal to pity	1	7	1	1	1	2	-	-	3	1	6	5	2	30
Appeal to force	4	3	1	-	1	1	-	-	-	-	2	1	-	13
Appeal to consequences	-	-	2	-	-	-	-	-	1	1	-	1	-	5
Total	16	29	14	11	14	14	7	24	23	37	24	51	28	290

Note. Data extracted from Nvivo®.

It can be observed that in the year of the tragedy in Mariana, since Vale S.A. was only the controller, there was no difference in the fallacies used, as it was supposedly not directly responsible for the company, so there was not much information about what happened with Samarco. However, in 2019, the fallacies of appeal increased

significantly compared to the previous year, by around 61%, going from 23 to 37 fallacies mentioned in the reports.

When analyzing the types of fallacies of appeal, there is a notable emphasis on the Fallacy of Appeal to the People, with 194 passages identified over the years. This type of fallacy refers to phrases that replicate what society expects to hear from companies, something that comforts the reader, for example:

> "Life comes first, a value recognized and lived day by day by all Vale employees, and we want to increasingly put into practice Genuine Active Care - taking care of oneself, others, and allowing others to take care of us - beyond the borders of our company" (p. 11, 2015, our translation).

This passage was extracted from the report of the same year as the incident in Mariana, in which Vale S.A.'s joint venture, with over 50 million m³ of tailings, affected cities and indigenous reserves in two Brazilian states, in addition to causing other environmental damage (Federal Public Ministry [MPF], 2015). After eight years, only the community of Bento Rodrigues in Minas Gerais received new houses, with several pending lawsuits from the more than 200,000 affected individuals, and the amounts in question can reach the equivalent of almost US$ 28 billion in compensation (Globo, 2022).

Furthermore, in the analysis using NVivo®, the most frequently used words in the Appeal category were identified, as shown in Figure 1 below:

Figure 1. Word Cloud

Note. Our translation, as the original language of the reports is Portuguese.

It can be observed that most of the fallacies resolve around words such as 'company,' 'people,' 'community,' and 'development.' Through content analysis, it can be inferred that the company indeed emphasizes keywords highlighted in uppercase for impactful phrases that resonate with the public's concerns, attempting to emotionally engage or captivate readers.

Further analysis using NVivo® enables the creation of a matrix of fallacies with reports before and after 2015, i.e., before and after the first accident, as shown in Table 3.

Table 3. Matrix of appealing fallacies by period before and after accidents

Fallacies	Before Accident	After Accident
Appeal to the people	48	146
Appeal to prejudice or emotion	14	34
Appeal to pity	11	19
Appeal to force	9	4
Appeal to consequences	2	3
Total	84	206

Note. The period evaluated is from 2010 to 2022.

The matrix shows an increase in the total number of appeal fallacies by 145%. The table also indicates that all fallacies increased, except for the appeal to force fallacy, possibly because it raised implicit questions about imposing conditions on employees. Although not explicitly stated, it was observed during the analysis that the company was more flexible regarding diversity, inclusion, and gender-related discussions.

3.2 Quantitative Analysis

To corroborate the findings of the qualitative research, a hypothesis test was employed without implying a causal relationship. For this purpose, the non-parametric Wilcoxon test was used, as it is suitable for a single sample, comparing groups under different conditions to determine if there is a significant difference between two paired conditions (Fávero & Belfiore, 2017). In this phase of the research, the focus was on evaluating Hypothesis 1, which aims to determine whether there is a difference in appeal fallacies before and after 2015. The results of the paired groups test for appeal fallacies are presented in Table 4.

Table 4. Wilcoxon test comparison of appealing fallacies

sign	obs	sum ranks	expected
Positive	2	5	7.5
Negative	3	10	7.5
Zero	0	0	0
Total	5	15	15
Unadjusted variance		13.75	
Adjustment for ties		0	
Adjustment for zeros		0	
Adjusted variance		13.75	
Ho: appeal_fall_bef	=	appeal_fall_after	
z	=	-0.674	
Prob > |z|	=	0.5002	
Exact Prob	=	0.625	

Note. The period evaluated is from 2010 to 2019, due to data pairing.

Based on the results, it can be observed that the null hypothesis (H0) suggests equality in the medians of the two conditions, whether before or after the 2015 accident. In the test statistic 'z,' the sum of the ranks of differences between pairs is negative (-0.674), but its absolute value is not exceptionally large. This is reflected in the p-value (Prob > |z|) of 0.5002, which exceeds the typical significance level of 0.05. Therefore, there is no statistically significant evidence to reject the null hypothesis. This lack of significance might be explained by the limitation of having only the last three years of paired data.

Continuing, Table 5 presents the Spearman correlation based on the study variables.

Table 5. Spearman correlation with significance level

	socioenv_inv	env_jud_dep	prov_env_proc	samarco_prov	prov_dec_dams	brumar_prov	appeal_fall	env_cont_liab	accid	law
socioenv_inv	1									
env_jud_dep	-0.5392	1								
	0.0572									
prov_env_proc	0.4505	-0.5089	1							
	0.1223	0.0757								
samarco_prov	-0.4017	0.8247	-0.4884	1						
	0.1737	0.0005	0.0904							
prov_dec_dams	-0.2282	0.6586	-0.0805	0.8612	1					
	0.4534	0.0144	0.7937	0.0002						
brumar_prov	-0.3154	0.6552	-0.1007	0.84	0.9754	1				
	0.2938	0.0151	0.7435	0.0003	0					
appeal_fall	-0.0996	0.4931	-0.2573	0.6081	0.696	0.6555	1			
	0.7462	0.0869	0.3961	0.0274	0.0082	0.015				
env_cont_liab	-0.4176	0.542	-0.3352	0.5693	0.3355	0.3087	0.0802	1		
	0.1557	0.0557	0.2629	0.0423	0.2624	0.3048	0.7945			
accid	0.6339	-0.8463	0.5071	-0.7779	-0.5161	-0.5161	-0.3404	-0.8452	1	
	0.02	0.0003	0.0769	0.0017	0.071	0.071	0.2551	0.0003		
law	-0.244	0.4642	0	0.7699	0.894	0.894	0.5159	0.3416	-0.433	1
	0.4218	0.1101	1	0.0021	0	0	0.0711	0.2534	0.1394	

Note. Stats (rho p) pw (obs=13).

Table 5 presents the relationship between socio-environmental investment and the other variables under study. This arrangement was based on Hypothesis 2, which is examined in this article with the aim of verifying whether investments in sustainability areas can reduce environmental liabilities, i.e., establish a negative and significant relationship.

Firstly, it is important to clarify what is considered an environmental liability in the study variables: environmental judicial deposit (env_jud_dep); provision for environmental processes (prov_env_proc); provision for Samarco (samarco_prov); provision for Brumadinho (brumar_prov); and provision for the decharacterization of dams (prov_dec_dams).

From the data, it was observed that the studied liabilities are negatively impacted by investment, with the exception of the provision for environmental processes. The same applies to the fallacies, 'law,' and contingent liability, indicating that higher investment in environmental assets is associated with lower costs for provisions or contingencies. However, none of these associations is statistically significant, so we cannot fully accept the null hypothesis.

However, when looking at the other variables, it can be stated that investments can impact disasters. When related to the dummy variable 'accident,' this relationship is positive and significant with a p-value of 0.02.

To confirm this, Figure 2 shows the value of socio-environmental investment over the years under study, and it can be seen that this investment has been decreasing, especially in 2020, and reached its peak in 2022, precisely with the implementation of projects for the decharacterization of dams.
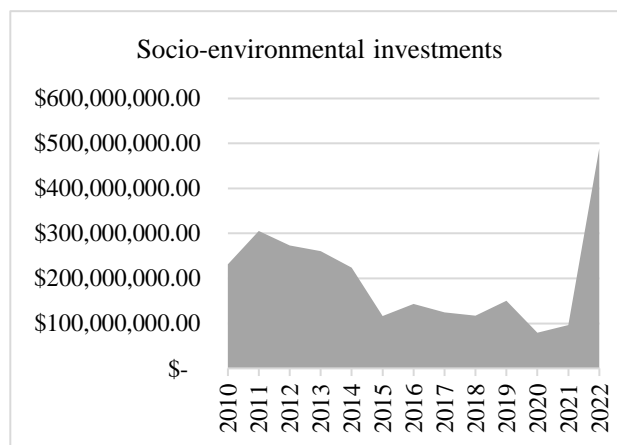
Figure 2. Socio-environmental investment from 2010 to 2022

Note. Values converted into dollars equivalent to R$0.2035623 in Sep/2023.

Based on the correlation analysis, several other significant associations were found that are important for understanding the study. Positive and significant associations were observed between appeal fallacies and provisions for Samarco (0.0274), dams (0.0082), and Brumadinho (0.0150), suggesting that after accounting for these liabilities, there was an increase in appeal fallacies.

When we evaluate the 'accident' variable, a strong and significant relationship is observed with judicial deposit (0.0003), provisions for Samarco (0.0017), and contingent environmental liability (0.0003). Considering that the baseline for the 'accid' dummy was the 2015 Samarco tragedy, controlled by Vale S.A., it becomes apparent that the association is more closely related to events related to Samarco rather than the 2019 accident, explaining the lack of association with the Brumadinho provision.

Conversely, the 'law' dummy is strongly and significantly associated with provisions for Samarco (0.0021), dams (0.0000), and Brumadinho (0.0000), indicating that the Feij ão Dam accident did have an effect on the amendment of Law n. 14,066/2020, which prohibited upstream dams.

Conversely, the 'law' dummy is strongly and significantly associated with provisions for Samarco (0.0021), dams (0.0000), and Brumadinho (0.0000), indicating that the Feij ão Dam accident did have an effect on the amendment of Law n. 14,066/2020, which prohibited upstream dams.

Other expected results include a strong and significant relationship between dam decharacterization and provisions for Brumadinho (0.000) and Samarco (0.002). Another interesting point is that once the compensation liability for the damages in Mariana was recognized, almost all variables had a significant association, except for

processes predating the accident and, logically, socio-environmental investments, for which it cannot be determined which were directed to Vale S.A.'s subsidiary.

Another variable for which a positive and significant association was expected is judicial deposits with the liabilities under study: provisions for Samarco (0.0005) with a strong association, provisions for dams (0.0144), and Brumadinho (0.0151). However, where it was expected that a higher value would be recognized after the accidents was in the contingent liability variable, based on Prospect Theory, a fact that was only observed in its positive and significant relationship with the Samarco provision (0.043).

Considering of this fact, a paired T-test was conducted, as this variable has normal data. Thus, a comparison was made between the group before and after the first accident to determine if there was a significant difference in this variable over time, as shown in Table 6.

Table 6. Paired t test with environmental contingent liabilities

Variable	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf. Interval]	
env_cont_liab_bef	5	4.73E+08	1.25E+08	2.80E+08	1.25E+08	8.20E+08
env_cont_liab_after	5	1.11E+09	1.18E+08	2.63E+08	7.83E+08	1.44E+09
diff	5	-6.37E+08	1.71E+08	3.82E+08	-1.11E+09	-1.62E+08
mean (diff) =	mean (env_cont_liab_~f - env_cont_liab_~r)				t =	-3.7236
Ho: mean (diff) =	0			degrees of freedom =		4
Ha: mean (diff)	< 0	Ha: mean (diff) !=	0	Ha: mean (diff)	> 0	
Pr (T < t) =	0.0102	Pr (| T | > | t |) =	0.0204	Pr (T > t) =	0.9898	

Note. Values converted into dollars equivalent to R$0.2035623 in Sep/2023.

Despite not being a hypothesis raised in this research, it is believed that there is a difference between the means of the unaccounted environmental liabilities after the accident. Therefore, for analysis, a two-tailed p-value was used because it is a probability measure often employed to determine if there is a difference after a change in groups, distinguishing before and after some event.

With that said, Table 6 showed a Pr($|T| > |t|$) = 0.0204, which represents the measure in both directions. Accepting a Type I error of 5%, this result suggests rejecting the null hypothesis (H0) and concluding that there is statistically significant evidence that there is a difference between the paired contingent environmental liabilities, i.e., there were changes in the contingent environmental liability after 2015.

This difference in absolute values amounts to more than $3 billion when comparing only the five years before and after the Mariana events. If we compare the 2010 values with the 2022 balance, the difference amounts to over $1 billion. These changes raise some questions, such as many values are still not recorded in the accounting, and the company should be concerned about these financial risk prospects. This trend of increasing allocation in contingent liabilities is not limited to environmental data investigated by this article; it is much more extensive, covering labor, tax, and civil liabilities, among others.

4. Discussion

This research aimed to analyze the potential increase in persuasive fallacies in the socio-environmental reports of Vale S.A., focusing on the accidents that occurred in the cities of Mariana and Brumadinho in the state of Minas Gerais, Brazil. In other words, the study aimed to determine whether these communications were geared towards self-promotion or the use of common sense to convince society of ideas that they would like to hear.

In this context, persuasive fallacies, defined as statements made with the intention of persuading the listener to hold a certain opinion through the use of emotional appeals, appeals to pity, appeals to popular consensus, or appeals to the consequences that may result from disagreeing with the speaker, were examined.

Given the two accidents that occurred in Brazil involving dams in the municipalities of Mariana (2015) and Brumadinho (2019), and considering that Vale S.A. was jointly responsible for the tragedy of its subsidiary, Samarco, this article expected an increase in the use of fallacies in the reports after these events, based on the Theory of Fallacies.

However, the quantitative results indicated a similarity between the medians of the fallacies under study in the periods before and after the first accident. However, when comparing the data extracted from the content analysis, it was confirmed that there was a 145% increase, mainly in the fallacy of appealing to the people, in response to justifications provided to the affected communities.

Other findings from the research suggest that environmental investment expenditures tend to reduce

environmental liabilities but without a significant relationship. It was also observed that contingent environmental liabilities increased by $3 billion after the accidents, which may impact the company's financial risk in the future, following Prospect Theory.

Additional inferences can be explored in future studies, such as the materiality of the reports and their relationship with fallacies, adding other mining companies for comparison, or even conducting a difference-in-differences study with a control group that did not have accidents and relating it to Law n. 14,066/2020. As practical implications, one can evaluate how these fallacies impact the reader's decision-making and future work can be conducted after the implementation of S1, which aims to standardize sustainability information. Therefore, the results of this research primarily aim at improving the quality of socio-environmental information for its main stakeholder, society.

Acknowledgments

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Notes

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