

ACCRUAL-BASED COST–BENEFIT EVALUATION OF FABA WASTE TREATMENT PRACTICES IN THE NATIONAL FERTILIZER INDUSTRY

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Abstract— This study examines policy frameworks for circular economy (CE) implementation through the utilization of Fly Ash and Bottom Ash (FABA) as a biochar-related resource to support soil revitalization and climate change mitigation in Indonesia's fertilizer industry. Positioned within the context of State-Owned Enterprises (SOEs), the study addresses the gap between technical waste treatment practices and strategic, policy-oriented evaluations of efficiency, scalability, and socio-economic impact. Employing a quantitative research design, primary internal data from three fertilizer subsidiaries located in Java, Sumatra, and Kalimantan are analyzed using an accrual-based cost–benefit analysis framework. The analysis compares internal waste disposal scenarios with external waste utilization through inter-industry collaboration. The results indicate that waste utilization strategies consistently outperform direct disposal in terms of cost efficiency and value creation. Companies in Sumatra and Kalimantan experience substantial cost reductions, while the Java-based company achieves net positive returns due to lower logistics costs and closer proximity to utilization partners. These findings demonstrate that circular economy implementation not only reduces environmental burdens but also enhances economic performance through integrated revenue streams, including environmental and social value. This study contributes to the literature by positioning FABA utilization as a strategic policy instrument that aligns SOE performance indicators, national development priorities, and Sustainable Development Goals (SDGs), offering actionable insights for policymakers and industry stakeholders.

Keywords— Circular economy, FABA utilization, cost–benefit analysis, accrual-based accounting, state-owned enterprises, industrial waste management, climate change mitigation

1. INTRODUCTION

Amid increasing global uncertainty related to environmental degradation and resource sustainability, corporations and industries face growing challenges in balancing industrial activities with their social and environmental consequences. This condition has raised critical concerns regarding how industrial development can continue without exacerbating ecological risks while still contributing to national welfare. In Indonesia, this challenge is particularly relevant for State-Owned Enterprises (SOEs/BUMN), which are expected to act not only as profit-oriented entities but also as key drivers of sustainable national development. In this context, the Ministry of SOEs has formalized performance expectations through Ministerial Regulation Number PER-1/MBU/11/2020, which mandates five core Key Performance Indicators (KPIs) for SOE directors: economic and social value creation for the nation, business model innovation, technological leadership, human capital management, and investment value enhancement (Antara News, 2020). Among these KPIs, the creation of economic and social value is closely aligned with the principles of the Circular Economy (CE), which emphasizes resource efficiency, waste minimization, and value retention across production cycles. Accordingly, the integration of CE practices within SOEs is not merely a managerial option but a strategic obligation to ensure that business processes generate broader societal and environmental

benefits beyond financial returns.

The relevance of CE implementation is evident in Indonesia's fertilizer industry, particularly within the Pupuk Indonesia Group, which has embedded circular economy principles into its corporate values, emphasizing the maximization of economic and social benefits for the country (Pupuk Indonesia, 2021). However, despite this commitment, industrial waste—especially hazardous and toxic waste (B3)—remains a persistent and escalating challenge. National data indicate that land contamination by B3 waste increased by more than 250% in 2019 (Maulidya, 2020), with major contributions originating from critical sectors such as mining, oil and gas, manufacturing, agriculture, and supporting industries (Yunianto, 2020). This trend underscores the urgency of effective waste management strategies that are both environmentally sound and economically viable. The regulatory framework in Indonesia, including Government Regulation Number 22 of 2021 and earlier legislation on hazardous waste management, obliges all waste-generating entities to process and manage their waste responsibly. Within the fertilizer industry, Fly Ash and Bottom Ash (FABA), a by-product of coal combustion, has long been recognized as a potential resource rather than merely a disposal burden. Several fertilizer subsidiaries have adopted high-temperature boiler technologies to neutralize FABA and convert it into usable materials for infrastructure development, such as lightweight bricks, cement additives, paving blocks, land stabilization materials, and polymer-based products (Ekaputri et al., 2020). These applications are consistent with national priorities outlined in the National Medium-Term Development Plan (RPJMN) 2020–2024, which identifies infrastructure development and socio-economic strengthening as critical sectors.

Despite these advancements, existing practices largely focus on technical feasibility and regulatory compliance, with limited systematic evaluation of efficiency, scalability, and broader socio-economic impacts. Moreover, while circular economy narratives are frequently cited in policy and corporate discourse, empirical studies that critically assess FABA utilization as an integrated CE strategy—particularly within SOEs and in alignment with national development goals and the Sustainable Development Goals (SDGs)—remain scarce. This reveals a clear research gap concerning how circular economy principles can be operationalized more efficiently and strategically in waste-intensive industries, beyond isolated technological solutions. Therefore, this study aims to address this gap by examining the role of circular economy implementation in optimizing FABA utilization within Indonesia's fertilizer industry. Specifically, the study seeks to (1) assess current FABA management practices from an efficiency and impact perspective, (2) analyze their alignment with circular economy principles, national policy frameworks, and SOE performance KPIs, and (3) formulate strategic recommendations that enhance economic, environmental, and social value creation. By doing so, this research offers a novel contribution by positioning FABA not only as a waste management issue but as a strategic circular economy lever that supports sustainable industrial operations, national development objectives, and SDG commitments simultaneously.

2. LITERATURE REVIEW

2.1. Circular Economy

The circular economy (CE) can be understood as a regenerative economic paradigm aimed at reducing systemic risks by slowing, closing, and narrowing resource flows, while simultaneously restructuring economic and environmental development pathways (Geissdoerfer et al., 2017). From a broader perspective, CE is also conceptualized as an integrated ecosystem in which the economy and the natural environment form a unified and interdependent cycle, requiring both systems to coexist and operate in a balanced and mutually reinforcing manner (Bigliardi & Filippelli, 2021). These perspectives collectively emphasize that CE seeks to establish continuous material circulation through the efficient utilization of raw materials and the minimization of environmental impacts throughout production and consumption processes. Viewed as a comprehensive process, CE incorporates human well-being and ecosystem functionality into the entire economic model, encompassing planning, resource allocation, procurement, production, and reprocessing activities (Murray et al., 2017). Accordingly, CE can be defined as an industrially embedded system in which all key stakeholders are expected to contribute to the development of a sustainable, well-planned, and scalable business ecosystem. This system requires the active involvement of multiple actors, including regulators who provide policy direction, facilitators who enable implementation, and companies that act as the primary drivers of innovation and system integration.

From a profitability perspective, the adoption of circular economy practices has the potential to generate substantial benefits in the form of new revenue streams, enhanced resource productivity, and long-term business continuity. However, realizing these benefits requires managers and practitioners to develop new

competencies and organizational capabilities, particularly in balancing linear and circular operational models. This challenge is further intensified by dynamic external factors such as rapid technological change and market volatility (Hopkinson et al., 2018). Empirical evidence suggests that well-implemented CE processes yield measurable outcomes, demonstrating positive impacts not only on environmental performance but also on socio-economic development, ultimately contributing to aggregate national income growth (Ungerma & Dědková, 2020).

2.2. Accrual Basis

From an accounting perspective, the accrual basis serves as a fundamental mechanism for measuring and analyzing the relationship between revenues and expenses across organizational decision-making processes. Accrual accounting enhances the informativeness of earnings, particularly in short-term performance assessments characterized by volatility in working capital requirements, investment and financing activities, and extended operating cycles. Under such conditions, cash flows frequently fail to capture underlying economic performance due to timing differences and mismatches between cash receipts and payments (Dechow, 1994).

From a managerial perspective, prior studies indicate that accrual-based accounting is more efficient than cash-based accounting in supporting managerial effort allocation, especially in the context of risk management under uncertainty and moral hazard conditions (Kwon, 1989). This suggests that accruals are directly linked to operational decision instruments and their resulting income outcomes. Beyond their role in contemporaneous performance evaluation, accruals also provide predictive information regarding future earnings. Although some empirical findings report adverse implications associated with accruals, evidence consistently demonstrates that accrual components remain statistically significant determinants of future earnings performance (Casey et al., 2017).

3. METHODS

From a methodological standpoint, this study adopts a quantitative research design utilizing primary data obtained from internal sources within a single State-Owned Enterprise (SOE) holding. The data are employed to conduct a cost-benefit analysis as the principal decision-selection method. The sample consists of three subsidiary companies, each representing one of Indonesia's major islands—Java, Sumatra, and Kalimantan—which collectively account for the highest levels of Fly Ash and Bottom Ash (FABA) production within the holding. Overall, this research is structured in accordance with the research onion framework, encompassing the philosophical stance, research approach, methodological choice, research strategy, time horizon, and data collection techniques. The application of this framework ensures methodological coherence and systematic alignment between the research objectives, data selection, and analytical procedures. The conceptual structure of the study, as guided by the research onion model, is illustrated in the following Figure 1.

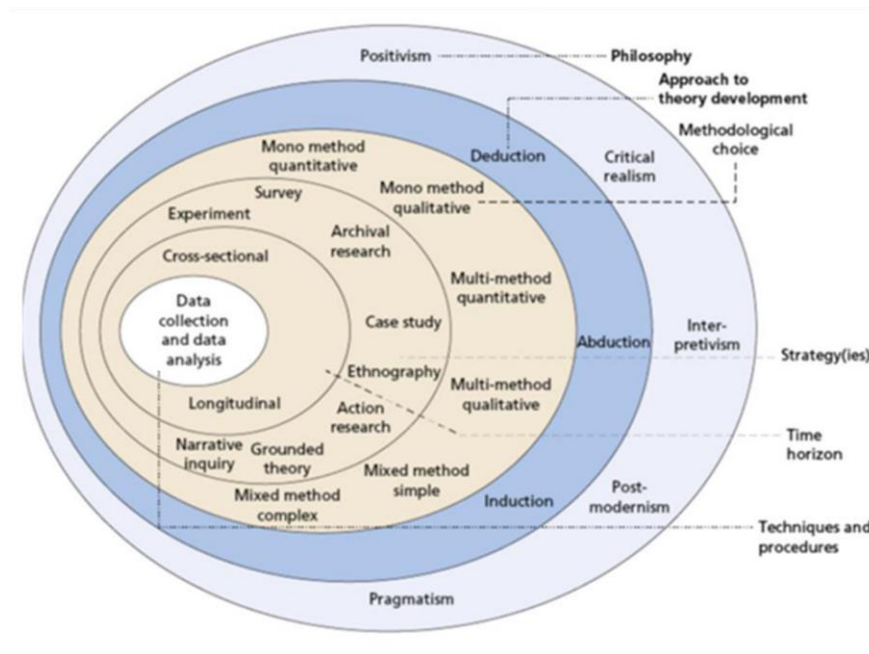


Figure 1. Saunders Research Onion Framework (Saunders et al., 2023)

This study is conducted within an interpretivist philosophical paradigm, which emphasizes the role of human experience, values, and contextual understanding in social science research, particularly in the analysis of economic decision-making (Greene, 1992). This philosophical stance is reflected in the study's focus on selecting optimal decisions based not only on economic efficiency but also on environmental impacts and associated benefits. Accordingly, decision quality is evaluated through the integration of value creation and environmental performance considerations. Consistent with the interpretivist perspective, this study adopts a deductive research approach. Deductive reasoning enables the application and translation of established theoretical frameworks into new empirical contexts, thereby facilitating the generation of refined insights based on prior knowledge (Elo & Kyngäs, 2008). In this study, the deductive approach is employed to relate existing theories and empirical evidence to current industry conditions, with the objective of formulating innovative solutions for both the company and the broader fertilizer industry.

In terms of research strategy, this study utilizes archival research by analyzing internal historical data obtained from three selected companies that have implemented Fly Ash and Bottom Ash (FABA) waste treatment practices. Archival research allows for the systematic examination of accumulated historical records from multiple perspectives, thereby enhancing analytical depth and contextual understanding (Das et al., 2018). The use of past data and documented practices provides a robust basis for problem-solving, particularly in addressing business and operational challenges. With respect to the time horizon, this study adopts a cross-sectional design. The cross-sectional approach is applied to analyze historical data within a defined time frame in order to capture the current conditions and identify prevailing problems. This design enables the study to assess existing practices and outcomes without tracking changes over extended periods. By integrating context, theory, and methodological choices in accordance with the research onion framework, the overall structure and logic of the study can be illustrated as following Figure 2.

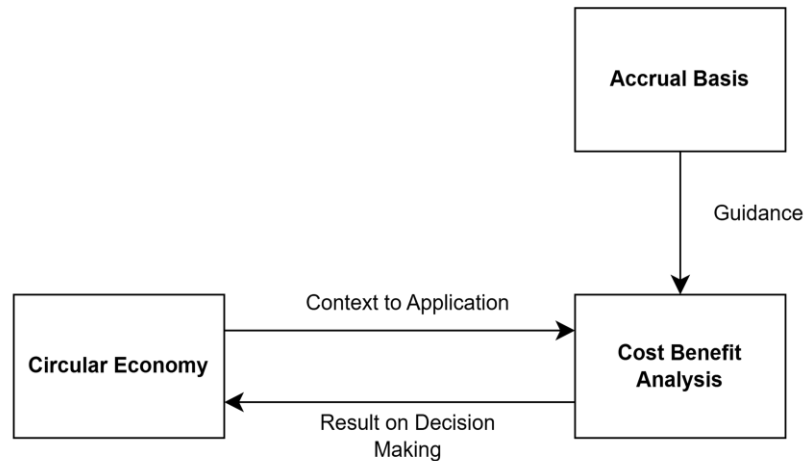


Figure 2. Relationship between Circular Economy Context, and Accrual Basis through Cost Benefit Analysis

Within the contextual framework of this study, the circular economy serves as the overarching objective for redefining profitability through an environmentally friendly and regenerative approach. Rather than viewing profitability solely in financial terms, the circular economy framework emphasizes the integration of economic value creation with ecological sustainability and resource regeneration. At the technical level, accrual-based accounting provides a robust measurement mechanism for capturing the relationship between expenditures and earnings. This capability enables a more comprehensive representation of economic scenarios, which is essential for conducting cost–benefit analysis under an accrual accounting framework. Cost–benefit analysis functions as a systematic decision-support instrument designed to assess the economic justification of expenditures by evaluating whether the anticipated benefits outweigh the associated costs, thereby ensuring the efficient allocation of financial resources and the maximization of value for money (Keith-lucas, 1973).

Furthermore, cost–benefit analysis operates as an integrative framework that consolidates multiple analytical instruments, organizes them into a coherent system, and synthesizes the results into relevant and decision-oriented information (Robinson & Hammitt, 2011). When applied within an accrual-based context, cost–benefit analysis enables the evaluation of expenditures and earnings beyond immediate cash flows, thereby capturing longer-term economic and environmental impacts. Accordingly, the integration of circular economy principles with accrual-based cost–benefit analysis establishes an analytical framework capable of systematically assessing investment decisions by balancing financial performance, environmental sustainability, and value creation. This framework can be elaborated as following Figure 3.

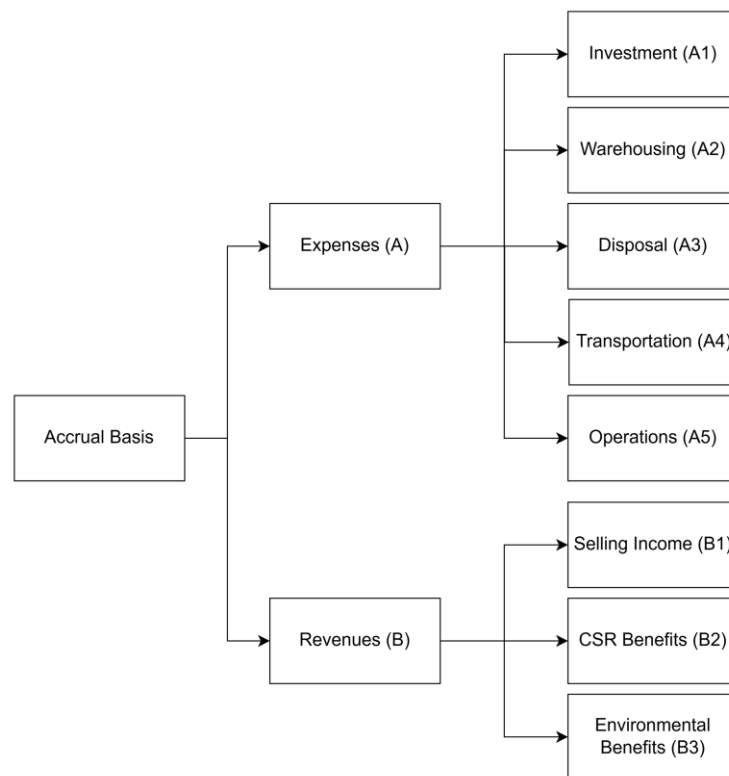


Figure 3. Accrual Basis Framework for Cost-Benefit Analysis

Within the accrual-based framework of revenues and expenses applied in this study, several key elements are identified as essential assessment components. From the expenditure perspective, the analysis incorporates various operational cost categories that directly and indirectly influence Fly Ash and Bottom Ash (FABA) waste treatment processes under different implementation scenarios. These expenditures include warehousing costs associated with storing FABA prior to further processing; investments in research, knowledge development, and supporting infrastructure; mandatory disposal costs for untreated or undeveloped waste as regulated by government policies; and transportation and operational expenses, including administrative and other supporting activities related to FABA treatment. Collectively, these cost components represent the comprehensive economic burden borne by firms in managing FABA waste.

From the revenue perspective, three principal elements are considered. The first is sales revenue generated from the commercialization of FABA as an input for downstream commodity production. The second and third elements relate to corporate social responsibility (CSR), including environmental and social benefits derived from waste utilization practices. These benefits may be realized either in the form of direct financial incentives or as implicit economic value associated with fulfilling social and environmental responsibilities toward local communities and ecosystems in production areas. By incorporating both expenditure and revenue components within an accrual-based analytical framework, this study enables a holistic evaluation of the economic feasibility and value creation potential of FABA utilization strategies. This integrated approach provides a foundation for the subsequent results and discussion by linking cost structures, revenue streams, and broader sustainability outcomes.

4. RESULT AND DISCUSSION

Through processes of discussion, dissemination, and decision-making, two primary implementation scenarios are identified as part of the circular economy (CE) framework operating as a regenerative mechanism. The first scenario involves internal waste handling, in which all processing activities are managed entirely within the firm. The second scenario entails external or second-hand waste handling, which requires the transportation of waste materials to third parties for further processing. In several stages of both scenarios, external collaboration or cross-industry support is required, generating mutual benefits through

inter-industry symbiosis. In the context of this study, the circular economy implementation process begins with both technical assessment and social judgment to establish clear objectives and a robust data foundation. Based on this foundation, relevant policies, agreements, and partnerships may be formulated to ensure regulatory compliance and to secure market access for waste utilization. These arrangements are essential to ensure that business processes align with applicable legal frameworks while enabling viable market opportunities.

Following the administrative and regulatory phase, the operational process of waste commodification is initiated, beginning with waste collection and classification and culminating in processed waste products ready for utilization. The resulting outputs may be recycled into marketable commodities, stored for future use, or disposed of as residual waste. However, decisions related to storage or disposal require careful evaluation in terms of both cost implications and potential value, given the physical limitations of storage capacity and the associated financial and social costs. Considering these constraints, strategic business agreements with appropriate market actors become critical to enhancing the overall circularity impact. Such agreements can optimize waste utilization outcomes while reducing long-term economic and environmental burdens. Within an accrual-based accounting framework, the financial implications of these alternative scenarios can be systematically evaluated through ratio-based comparisons across the three fertilizer companies operating under a single SOE holding, as presented in the following analysis.

Table 1. Accrual Calculations on Cost Benefit Analysis

Company		Company A (Sumatera Island)		Company B (Kalimantan Island)		Company C (Java Island)	
Waste Production (in Tons per Year)		35500		35000		7750	
Accrual Points	Aspect	Internal (Disposal)	External (Treatment)	Internal (Disposal)	External (Treatment)	Internal (Disposal)	External (Treatment)
Earnings	Sales Income		1.6		1.8		0.46
	CSR Benefits						
	Environmental Benefits		61.4		144		14.8
Total Earning Ratio		0	63	0	145.8	0	15.26
Expenditures	Investment	11.4	11.4				
	Warehousing	4	4	27	27		
	Disposal	153	9.2	240	14.4	24	1.4
	Transportation		83		129		13
	Operations						
Total Expenditure Ratio		168.4	107.6	267	170.4	24	14.4
Total Ratio Score		-168.4	-44.6	-267	-24.6	-24	0.86
Internal X External Handling Comparison		26%		9%		-4%	

Referring to Table 1, the results indicate clear differences in cost structures between internal waste disposal and partner-based waste utilization scenarios across the three sample companies. In the case of Company A located in Sumatra, the ratio of waste disposal costs derived from the company's historical internal calculations for the period 2018–2021 demonstrates a substantially higher financial burden compared to the waste utilization scenario involving external partners. As shown in Table 1, expenditures associated with partner-based waste processing account for only 26% of the total costs incurred under internal waste management, indicating significant cost efficiency when collaboration mechanisms are applied. A similar pattern is observed for Company B in Kalimantan, where Table 1 illustrates an even more pronounced cost disparity. The proportion of expenditures related to waste processing through partners represents only 9% of the total costs associated with internal waste disposal during the same historical period. Although waste transfer to third parties may still entail residual storage costs—given that certain waste fractions cannot be immediately transferred—the associated disposal costs remain relatively minimal. This outcome is based on the assumption that approximately 90% of FABA output can be utilized as commodities, thereby significantly reducing disposal-related expenses.

From the revenue and operational perspective, transportation costs remain a necessary component in partner-based scenarios, as waste materials must be relocated from production sites to utilization partners. However, as reflected in Table 1, these costs can be offset through mutually beneficial collaborations between waste-producing companies and partner industries that utilize FABA as input materials. Such collaborations contribute to overall economic efficiency while enhancing circularity outcomes. In the case of Company C in Java, which exhibits the lowest annual FABA production among the three sample companies, Table 1 likewise shows that internal waste disposal imposes a greater cost burden compared to partner-based utilization. However, unlike Companies A and B, Company C demonstrates the potential to generate additional income through waste sales and environmental benefits. This outcome is largely influenced by relatively lower disposal and transportation costs, attributable to smaller waste volumes and shorter distances between production sites and utilization locations. Consequently, the economic feasibility of waste utilization partnerships is particularly favorable in this case, reinforcing the role of spatial proximity and production scale in determining circular economy performance.

5. CONCLUSIONS

The implementation of circular economy (CE) practices within the observed companies is aligned with their corporate missions as well as their institutional role as State-Owned Enterprises (SOEs) under the Ministry of SOEs of the Republic of Indonesia. Both in terms of process and outcomes, these practices are also consistent with the objectives of the National Medium-Term Development Plan (RPJMN), particularly in strengthening economic growth through inter-industry collaboration, which has been increasingly promoted since 2020.

The findings from the cost-benefit ratio analysis provide empirical support for this alignment, indicating that waste utilization options offer greater internal efficiency for the companies compared to direct waste disposal. Rather than constituting an additional operational burden, CE-based utilization strategies contribute to cost optimization and value creation. This evidence reinforces the view that the circular economy framework generates positive impacts not only on economic performance but also on environmental outcomes by reducing pollution associated with industrial activities (Johl & Toha, 2021).

In the specific context of fertilizer companies operating under an SOE holding, the analysis demonstrates that direct waste disposal consistently results in significantly higher expenditure ratios than waste processing strategies involving external partners. This outcome is largely driven by the inclusion of income-related factors in the utilization scenario, particularly environmental value and revenue derived from waste-based commodities. In the cases of companies located in Sumatra and Kalimantan, both scenarios yield cost reductions; however, the waste processing option exhibits substantially lower overall costs. By contrast, in the case of the Java-based company, waste processing not only reduces costs but also generates net profits, as total revenues exceed associated expenditures. This result reflects the advantages of lower transportation and disposal costs, as well as closer proximity to utilization partners. It also highlights the effectiveness of collaboration with third-party companies in marketing waste outputs, even when transaction volumes remain relatively limited. Such collaborative practices illustrate a growing commitment to synergy within the SOE ecosystem and demonstrate the practical feasibility of circular economy implementation as part of an integrated industrial strategy.

6. AUTHORS CONTRIBUTORS

Conceptualization, A.H.N. and S.B.A.; Methodology, A.H.N. and S.B.A.; Validation, A.H.N.; Formal analysis, A.H.N.; Investigation, A.H.N. and S.B.A.; Resources, A.H.N. and S.B.A.; Data curation, A.H.N. and S.B.A.; Writing—original draft preparation, A.H.N. and S.B.A.; Writing—review and editing, A.H.N. and S.B.A.; Visualization, S.B.A.; Supervision, A.H.N.; Project administration, A.H.N.; Funding acquisition, A.H.N.

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