Model of Sustainable Belawan Harbor Waters Pollution Management Scheme

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Abstract

This study aims to analyze the impact of industrial activities on water quality in Belawan Port, Medan City. The methods used included field surveys, water sampling, and in-depth interviews with stakeholders and communities around the harbor. The results showed that industrial activities at the port significantly affected water quality parameters such as acidity, heavy metal concentration, and the number of pathogenic microorganisms. In addition, the socio-economic conditions of the community around Belawan Port also affect awareness of the environment and the cleanliness of the waters. This study concludes that water pollution management in Belawan Harbor requires an integrated approach between the government, port management, industry, and local communities. Collaborative efforts are needed to implement more effective and sustainable policies to maintain environmental sustainability in this port area. Key recommendations include the establishment of an Integrated Water Quality Management Team and increased active participation from all stakeholders in keeping the waters and environment around Belawan Port clean.

Keywords: *Sustainable, Management, Pollution, Waters, Harbor.*

Introduction

Waters are areas that consist of water, usually in the form of seas, rivers, lakes, or reservoirs. Waters can be freshwater (freshwater) or marine waters (seawater). Freshwaters are usually rivers, lakes, or reservoirs that are not connected to the sea, while marine waters are areas connected to the ocean or sea. Waters have an important role in ecosystems and various aspects of life, such as natural resources, tourism, and the economy of the people living around them (Thamrin et al., 2022; Samdara, 2017). Waters can support the improvement of the community's economy in terms of agriculture, industry, tourism, energy, food security, and infrastructure development. This explains that there is a community dependence on water in various sectors.

One of how the community uses water is by making ports. Large and strategic sea areas allow ports as ship berths and loading and unloading facilities, affecting the economic sector and community climate in the Indonesian region (Parwati et al., 2024). Ports are also used as transportation to smooth the wheels of the economy, strengthen national unity, and affect aspects of national and state life so that ports can be used as supporters, drivers, and drivers for the growth of potential but undeveloped areas (Mutia, 2015). In domestic trade, ports help increase trade activities in the region, while in international trade, ports become bridges between countries that help increase global economic growth (Dirhamsyah et al., 2024). With the right policy support, ports can utilize the potential of international trade for economic growth. In addition, the importance of building modern port facilities and efficient operations helps maintain Indonesia's competitiveness in the global market.

Behind the significant benefits of ports for the community's economy, the use of ports causes an increase in industrial activity in water areas. The Port serves as a distribution center for goods and services, which attracts various industries to settle and operate in the area. This certainly hurts the waters around the Port. Increased industrial activity in the Port can increase industrial waste emissions into waters, such as liquid waste, gas, and hazardous particles, resulting in a decrease in water quality (Salsabila & Basyaiban, 2022). A decrease in water quality can affect the balance of aquatic ecosystems, leading to a decrease in fish

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production (Mulyadi & Atmaja, 2016). Water pollution is caused by water transportation used for trade activities and causes pollution.

The impact of water damage causes an increasing burden of expenditure by the government because it has to carry out infrastructure improvements. For this reason, it takes the role of the government and the community to prevent and overcome the problem of water pollution. The government needs to implement regulations on industrial waste disposal, agricultural runoff, and water management. Water monitoring and water quality enforcement must be maintained together with the community by providing understanding and raising public awareness to protect each other's waters. These government initiatives demonstrate a commitment to addressing water pollution and ensuring the long-term sustainability of water resources. By implementing these measures, the government can protect public health, preserve aquatic ecosystems, and support economic growth.

The government has taken many steps, including policy implementation for law enforcement. However, there are obstacles and barriers in implementing policies to safeguard and manage waters from the impacts of industrial activities. The attitude and behavior of the community and stakeholders involved in the implementation of water policies can be an obstacle because the lack of coordination between stakeholders can cause failure in policy implementation (Berliana & Adianto, 2022). The implementation of the policy still often fails because the need for replacement port facilities can hinder the relocation process of the loading and unloading port, so this is considered not by existing policies (Hanafi et al., 2023). This also happened to one of the ports in Belawan, Medan City. Belawan Port is one of the waterways with a high level of industrial activity. This research aims to conduct an in-depth analysis of the social conditions of the community around Belawan Port, focusing on the economic factors that affect their lives. In addition, this research will examine a model of a sustainable Belawan Harbor water pollution management scheme as a response to the environmental problems faced. The research will include the implementation of factors affecting pollution management based on George Edward III's (1980) theory, to provide recommendations for appropriate solutions for environmental management in the region.

Literature Review

Based on the previous explanation, this research draws on previous studies to find out how the water management model in the Port is different from other studies. Raising public awareness about their concern for the environment affects the management of water pollution (Irawanto & Afifudin, 2022). To manage waters in the Port, knowledge, supervision, and completeness of waste management facilities for ship crews affect marine pollution prevention behavior in the Port (Nursyamsu et al., 2022). The water resources management model can be carried out using technological advances (Sudaryanti et al., 2023). Water management also needs government support to issue regulations that can reduce marine environmental pollution (Efansyah & Basuki, 2021). Other research also confirms that holistically, water pollution management requires a regulatory framework, technological innovation, and stakeholder engagement (Oginah et al., 2023).

Effective risk management and response strategies are essential to address water pollution incidents in ports, and these include proactive risk assessment, early detection using advanced monitoring technologies, and coordinated response mechanisms involving multiple stakeholders (Chauhan et al., 2024). Prevention can be done to protect the water environment by monitoring the health of aquatic ecosystems (Sumudumali & Jayawardana, 2021). Creating an environmentally friendly Port that includes using renewable energy sources, reducing waste, and improving waste management (Sadri et al., 2021).

Damaging the balance of aquatic ecosystems, water pollution also has an impact on society. The main thing about the impact of water pollution is that it can affect public health (Farhan et al., 2023). The health impacts of water pollution can lead to increased healthcare costs, which can be a huge burden for individuals, communities, and governments. Water pollution can damage aquatic ecosystems, which can have a long-term impact on the survival of people who depend on these aquatic resources (Fauzan &

Milantara, 2024). In addition, water pollution can lead to reduced productivity in industries that depend on clean water, such as agriculture, manufacturing, and tourism, resulting in significant economic losses.

Method

This research used a qualitative descriptive approach to develop a comprehensive model of sustainable water pollution management in Belawan Port. The research methodology centered on in-depth field surveys and structured interviews with key stakeholders involved in environmental management and local communities (Creswell & Poth, 2016). Primary data collection was mainly done through in-depth interviews conducted with officials of relevant agencies, including the North Sumatra Provincial Industry, Trade, Energy and Mineral Agency, the North Sumatra Provincial Environment and Forestry Agency, and the North Sumatra Provincial Marine and Fisheries Agency. The interviews were conducted with the officials of the Department of Industry, Trade, Energy and Minerals of North Sumatra Province, Sumatra Watershed II Directorate General of Water Resources, Medan City Environment Office, and Medan Belawan Sub-district. The interviews aimed to shed light on the types of industries along the Deli River and Belawan River, environmental compliance, and community perspectives on pollution management.

Complementing the interviews, the literature review examined existing reports and documents related to water pollution, environmental regulations, and socio-economic impacts around Belawan Port. The research was conducted in stages to ensure systematic data collection and analysis: a preliminary survey established baseline information, followed by focused interviews to deepen insights and validate findings. Qualitative data was further thematically analyzed to discern patterns and formulate a sustainable model for water pollution management in Belawan Port. Throughout the research, strict ethical standards regarding consent, confidentiality, and data security were carefully adhered to to maintain the integrity of the research process. The research adopted a qualitative descriptive approach to develop a comprehensive model of sustainable water pollution management in Belawan Port. The research methodology centered on in-depth field surveys and structured interviews with key stakeholders involved in environmental management and local communities.

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Results and Discussion

Analysis of Social Conditions of Communities Surrounding Belawan Port

The analyzed social conditions of the community are briefly described as follows: The analysis of the social conditions of the communities around Belawan Port shows several important aspects that describe their lives. In terms of education, the majority of the population in Medan Belawan Sub-district has a high school level of education with a total of 29,342 people. In comparison, those with Diploma IV/Strata I education are 1,507 people, and Strata II is 84 people. Of the 400 respondents interviewed, the distribution of

education levels is SD (7.75%), SMP (30%), SMA (58.50%), Diploma (2.25%), and S1 (1.50%), reflecting the same pattern as the general population, namely the dominance of secondary education levels. In the economic sector, there are various types of businesses in Medan Belawan, including large, medium, and small industries (6 in total), hotels (13 units), restaurants and warungs (143 units), and trade (566 units). This diversity shows the dynamics of a fairly active economy in the area.

Living conditions also reflect the level of community welfare, with 74% of respondents living in permanent houses categorized as affluent, 19.50% in semi-permanent houses, 2% in makeshift seafront houses, and 4.50% in rental houses. In terms of environmental hygiene, the majority of respondents (98%) use family latrines that are considered healthy, with only 2% still using the river as a place to defecate. Fecal containment facilities mostly use septic tanks (90.75%), while a small proportion are channeled to local sewers (2.25%), beaches (1%), and rivers (6%). The pattern of waste disposal shows that 87% of the respondents dispose of waste in trash bins, although there are still those who dispose of it carelessly (5.50%), to the river (5%), and to the beach (1%). This indicates a fairly high awareness of environmental cleanliness among the majority of respondents.

Domestic wastewater disposal facilities also show concern for environmental health, where 44.50% use infiltration wells with adequate construction, 33% with simple construction, and 21% are channeled to the beach through local drainage channels. Based on this data, the community around Belawan Port has a medium level of education, various types of economic businesses, mostly permanent and healthy living conditions, and a fairly high awareness of environmental hygiene. However, there are still some things that could be improved in waste and wastewater management.

Economic Analysis of the Community Around Belawan Port

Medan Belawan Sub-district, which is the research area, has a population of 112,457 people in 2022, consisting of 57,573 men and 54,884 women. The kelurahan with the largest population is Belawan II (24,764 people), while Belawan Bahari has the smallest population (13,362 people). The population density in each kelurahan varies, with Belawan Bahagia having the highest density (19,728 people/Km²) and Belawan Sicanang the lowest (992 people/Km²). Overall, Medan Belawan sub-district has a density of 3,380 people/Km². The population in Medan Belawan's main occupations are diverse, including civil servants (PNS), private employees, casual daily laborers, teachers, farmers/gardeners, fishermen, traders, entrepreneurs, and sailors. Data from 2022 shows that the number of fishermen is 5,278 people or around 5% of the total population. Interviews with 400 respondents revealed that the most common profession was trader (29.50%), followed by housewife/laborer (25.50%), and fisherman (23.50%).

The income of fishermen varies, with modern fishermen (who use large boats or motors) earning around Rp. 2,750,000 - Rp. 3,850,000 per month. Meanwhile, traditional fishers (who use boats without motors) have a monthly net income of between IDR 480,000 and IDR 1,170,000. Interview data also showed that the majority of respondents (63.50%) had less than 4 family dependents, with most respondents' monthly expenditure (43.25%) in the range of Rp. 2,000,000 - Rp. 2,500,000. Local regulations stipulate that the waters around Belawan Port are not a capture fisheries zone, so fishers fish in waters around Deli Serdang Regency, including at the Belawan Ocean Fishing Port (PPSB). This condition directs fishermen's activities out of the port zone, adjusting to existing regulations.

Overall, the economy of the community around Belawan Port is affected by the presence of the port and fishing activities that are directed to more distant waters, following the zoning rules set by the local government. Infrastructure management and improvement, as well as business capital support, especially for fishermen, are the main concerns in improving the economic welfare of the local community.

Implementation of Sustainable Management of Belawan Port Waters Pollution

Water pollution management in Belawan Port is a challenge that requires a systematic and integrated approach to achieve environmental sustainability. For this reason, the modeling of management schemes must be based on an in-depth analysis of the key factors that influence the successful implementation of

environmental policies. George Edward III's (1980) theory provides a relevant framework, which includes four essential conditions: communication, resources, disposition/attitude, and bureaucratic structure.

Clear and consistent communication is a key foundation in ensuring that information related to water environment management is effectively conveyed to all relevant parties. Furthermore, the availability of resources, which include adequate staffing, accurate information for decision-making, sufficient authority, and necessary facilities, determines the successful implementation of the management program. The strong disposition or attitude of all implementers towards the program is also key in maintaining the sustainability of environmental management efforts. Finally, a bureaucratic structure based on standard operating procedures is fundamental to organizing the flow of work and policy implementation efficiently (Ridho et al., 2023).

In the context of Belawan Port, this introduction will highlight how these factors are applied and implemented to improve the condition of the marine environment sustainably. The analysis in the following table will provide a more detailed overview of the implementation and recommendations needed to improve water pollution management in this Port.

Table 1. Implementation Analysis of Belawan Harbor Waters Pollution Management

No.	Factor	Description	Implementation that has been carried out	Implementation that needs to be done
1	Communication	The process of delivering aquatic environmental management and monitoring by Belawan Port Management	Submit reports on the implementation of environmental management and monitoring of the Port of Belawan including the port water environment to regional and central environmental agencies (KLHK).	Reports on the implementation of environmental management and monitoring of Belawan Port also need to be submitted to the community around the port through the local village head. Submission of reports can be done through an institution
2	Resources	Still limited to Belawan Port management	1) Establishment of the environmental management field in the company's organizational structure 2) Equipping existing resources with training and certification related to port environmental management.	1) Involve the government and related stakeholders in the management of pollution of Belawan Port waters, such as KLHK, Provincial DLHK, City DLH, and surrounding industries 2) Include the community living around the port to participate in the management of pollution of Belawan Port waters 3) Stakeholder and community involvement needs to be done through an institution.
3	Disposition/ Attitude	Belawan Port Management is fully committed	1) Belawan Port Management applies the Green Port concept as part of sustainable port	Committed to continue to manage pollution of Belawan Port waters. In

		to implementing environmental management programs	management 2) Make a joint commitment with related parties, such as companies and industries in and around the port area, to be equally responsible for managing the water quality of Belawan Port waters under the coordination of the Belawan Port I Authority.	terms of holistic management, it is necessary to establish a management institution involving; central and local governments, Belawan Port, stakeholders and the community.
4	Bureaucratic Structure	Implementation of environmental management program at Belawan Port based on Standard Operational Procedure (SOP).	1) Conduct regular cleaning of the harbor drainage channel that empties into the water 2) Installing notice boards around the dock area, so as not to throw garbage into the sea. 3) Provide direction to fuel filling business actors so that there is no splashing of fuel during the transfer from the tank car to the ship. 4) Provide oil spill pollution prevention facilities (oil boom) in the waters of Belawan Port. 5) Cooperate with Syahbandar Belawan and the Port Authority to require ship owners not to discharge their solid waste and domestic liquid waste into the sea. 6) Work with Syahbandar and the Belawan Port Authority to require ship owners to replace the ship's ballast water in accordance with applicable regulations (in accordance with the provisions contained in the IMO / International Maritime Organization.	It is necessary to establish an Integrated Management Team involving the Central and Local Governments. Formulate a scheme for the participation of each group included in the Integrated Management Team.

Source: Data processing by researchers, 2023

Based on the analysis in Table 1. a joint commitment between the government, Belawan Port management, and the community/stakeholders is needed to manage water pollution sustainably. It is necessary to establish a proposed organization called the Belawan Port Water Quality Management Integrated Team. This organization aims to maintain and supervise environmental management for sustainable operations. According to Nadiroh (2023), environmental institutions are very important for the sustainability of ecosystems and environmental quality. The implementation of water pollution management at Belawan Port has shown significant steps but still requires improvement in some key aspects.

Port management has successfully submitted environmental management reports to regional and central environmental agencies, such as KLHK, reflecting a commitment to transparency and accountability. However, to engage the community more broadly, it is important to improve direct communication through village heads or local institutions. Meanwhile, limited human resources and facilities remain a constraint in aquatic environmental management. Closer collaboration with government, industry, and local communities is needed to expand available resources and increase participation in water pollution

management efforts. Port management's strong commitment to the Green Port concept has been reflected in the implementation of management programs. However, to maintain sustainability, it is necessary to establish an integrated management institution involving all stakeholders. This will ensure better coordination and integrated monitoring of the condition of the aquatic environment in accordance with well-implemented SOPs. Thus, the management of water pollution in Belawan Port can continue to improve towards a cleaner and more sustainable environment for all parties involved.

Program Plan for Preventing/Minimizing the Entry of Polluting Substances into Belawan Port Waters

Water quality management in Belawan Harbor requires a planned and coordinated strategy to reduce the impact of pollution from various sources. The Belawan and Deli River estuaries, as well as drainage channels from settlements and port land areas, are the main sources of pollutants that need to be addressed effectively. Wastes such as industrial wastewater, domestic wastewater, and domestic garbage contribute significantly to this pollution. Programs to prevent and minimize the entry of polluting substances into the waters of Belawan Port have been formulated in Table 2 below. These measures are designed to be managed by various parties, including the government, businesses, and relevant agencies such as the Medan City Environmental Agency, North Sumatra Provincial DLHK, and Medan City DLH. The aim is not only to maintain water quality but also to avoid negative impacts such as disturbance to aquatic life and social conflicts around the port.

By developing this plan, it is expected that a cleaner and healthier water environment will be created in Belawan Port, supporting the sustainability of the ecosystem and the welfare of the local community. Table 2 provides a clear picture of the pollution prevention strategies that need to be implemented immediately and effectively.

Table 2. Prevention/Minimization Program Plan for the Entry of Polluting Substances into Belawan Port Waters

No.	Waste Type	Waste Source	Manager	Supervisor	Management Plan
1	Domestic wastewater	Settlement activities and settlement facilities and infrastructure (restaurants, cafes, restaurants, school houses, etc.)	Government	- DLHK North Sumatra Province - DLH Medan City	Making Communal WWTP
2	Domestic waste (similar to household waste)	Settlement activities	Government	- DLHK Provinsi Sumatera Utara - DLH Kota Medan	-Providing waste disposal sites in appropriate locations - Dispose of waste regularly to landfill
3.a	Industrial wastewater	Industry operations	Business actors	- DLHK North Sumatra Province - DLH Medan City - Industry Agency - District apparatus - Sub-district apparatus	Treating wastewater until it meets the required quality standards before being discharged into water bodies

3.b	Fasyankes (Facility, Service, Health) wastewater	Health facility operations	Proponent/business actor	- DLHK North Sumatra Province - DLH Medan City - district officials	Wastewater treatment in WWTP/IPAL before being discharged into environmental media so that it meets the required quality standards

Source: Based on Field Observations, Year 2023

Table 2 presents the program plan to prevent or minimize the entry of pollutants into the waters of Belawan Port, involving different types of wastes from various sources. First, domestic wastewater from residential activities and facilities such as restaurants, cafes, and schools will be managed through the construction of communal WWTPs with supervision from DLHK of North Sumatra Province and DLH of Medan City. Secondly, domestic waste from households will be managed by providing appropriate temporary shelters (TPS) and regular disposal to landfills (TPA), also with supervision from the Provincial DLHK and DLH of Medan City. Then, industrial wastewater from industrial operations at Belawan Port is expected to be treated to meet quality standards before being discharged into water bodies, involving the Industry Office, sub-district, and village officials. In addition, wastewater from Facilities, Services, and Health (Fasyankes) must also be treated through WWTP/IPAL before being discharged into the environment.

The role of each group in the Belawan Port Water Quality Management Integrated Team is critical to achieving this goal. The Central Government, through the MoEF and the Ministry of Transportation, is responsible for regulations, permits, and general supervision of activities at the port. The local government, through the provincial DLHK and DLH of Medan City, plays a crucial role in the implementation and supervision of water pollution management. DLH Medan City is also expected to take an active role in the establishment of this management organization.

Belawan Port, represented by its main operator, PT Pelindo, has direct responsibility for port environmental management and supervision of operational activities, including wastewater management. Stakeholders such as industries around Belawan Port are obliged to contribute by responsibly managing their industrial waste before discharging it into the water environment. Ships using the port must also comply with domestic and solid waste management rules. Communities around the port are encouraged to play an active role in keeping the aquatic environment clean. Their participation is expected to increase environmental awareness and support ongoing monitoring and reporting of environmental conditions. By integrating all stakeholders through the Integrated Management Team, it is expected that this joint effort will be effective in managing and minimizing pollution of Belawan Port waters, maintaining the sustainability of port operations, and improving the quality of life for the surrounding community.

Model of Sustainable Management of Belawan Port Water Quality

The Belawan Harbor water quality management scheme model is systematically designed to address water pollution challenges with a comprehensive approach. The first stage in the model is data collection, which includes direct measurement of physical, chemical, and biological parameters of water, such as temperature, pH, dissolved oxygen, and the content of pollutants such as heavy metals. In addition, observations of pollutant sources from both point sources (such as industries) and non-point sources (such as stormwater runoff) are made to identify the origin of pollution. The results of these measurements and observations are then reported in a structured manner for further analysis.

The second stage is data analysis, where the collected information is evaluated to assess the water quality according to set standards. This process also includes the identification of key issues affecting water quality, such as the types and sources of dominant pollutants. Based on this evaluation, concrete action plans are developed to address the identified issues, including appropriate prevention and remediation strategies. The

implementation of water quality management becomes the focus of the third stage, which involves the implementation of preventive measures and countermeasures. This includes the construction of infrastructure for effluent management, the application of environmentally friendly technologies, and other mitigation measures. Regular monitoring of water quality is also integrated to ensure the effectiveness of the measures taken and to detect changes in water conditions in a timely manner.

Stakeholder engagement is a key aspect in the fourth stage, where active collaboration with industries, communities, and NGOs is emphasized. This cooperation includes organizing education and training programs on the importance of maintaining water quality, as well as efforts to increase community awareness and participation in environmental management. Evaluation and follow-up is the final stage of the model, which involves an in-depth review of the management results. The evaluation aims to assess the effectiveness of the strategies implemented and adjust the action plan based on the findings and feedback from the evaluation. In addition, periodic reports are prepared to provide transparency and accountability for the progress made in maintaining the water quality of Belawan Harbor waters.

Meanwhile, the organization of the integrated team in this model plays an important role in ensuring effective coordination between all parties involved. The team is led by a team leader who is responsible for the overall coordination of activities and ensuring the efficient implementation of the plan. The secretary and treasurer are in charge of managing the team's administration and finances. At the same time, divisions such as stakeholders, operations, supervision and monitoring, and education and community participation play specific roles according to their task specifications in maintaining water quality. Effective coordination and communication among team sections, as well as with all relevant parties, is key to success in this model. This ensures that every step taken is responsive to changing environmental conditions and supports the achievement of the long-term goal of maintaining optimal water quality in Belawan Harbor waters. Thus, this model not only strengthens technical efforts in environmental management but also promotes synergy between various stakeholders to create sustainable solutions to the environmental challenges faced.

Conclusion

The conclusion of this study highlights the complexities and challenges in managing water pollution in Belawan Harbor, Medan City. It was found that industrial activities at the port significantly affect the environmental quality of the surrounding waters, with widespread impacts including on the ecosystem and the health of local communities. The results of the analysis of the socio-economic conditions of the community around Belawan Port showed a predominantly middle level of education, a diverse range of economic businesses, and a high awareness of environmental cleanliness despite challenges in waste and wastewater management.

In addition, the implementation of sustainable water pollution management requires a systematic and integrated approach. A shared commitment from the government, port management, industry, and local communities is required to ensure the effectiveness of implemented policies and programs. Improvements in communication, adequate resource allocation, a positive attitude towards the environment, and an efficient bureaucratic structure are key to success in maintaining the sustainability of environmental management efforts in Belawan Port. The main recommendations of this study include the establishment of the Belawan Port Water Quality Management Integrated Team as the institution responsible for coordination and monitoring of the condition of the aquatic environment, as well as increased active participation from all stakeholders in maintaining the cleanliness and sustainability of the aquatic environment in this port.

References

Abbas, M., Jam, F. A., & Khan, T. I. (2024). Is it harmful or helpful? Examining the causes and consequences of generative AI usage among university students. International Journal of Educational Technology in Higher Education, 21(1), 10.
Ahmed, I., Farooq, W., & Khan, T. I. (2021). Customers' Perceptions and their Responses to Objectives of Islamic Banks–A Three-Wave Investigation. Asian Economic and Financial Review, 11(1), 43. al politics and job outcomes.

Berliana, V., & Adianto, A. (2022). Peran Stakeholder Dalam Implementasi Kebijakan Relokasi Pelabuhan Bongkar Muat Di Kawasan Free Trade Zone Kabupaten Karimun. Jurnal Ilmiah Muqoddimah/Jurnal Ilmiah Muqoddimah, 6(2), 484. https://doi.org/10.31604/jim.v6i2.2022.484-494

Chauhan, R., Kumar, S., & Jafri, M. A. (2024). Integrating Risk Management and Response: Water Pollution Incident Control in Urban Settings. 11th International Conference on Cutting-Edge Development in Engineering Technology and Science. https://doi.org/10.62919/ijoe0981

Creswell, J. W., & Poth, C. N. (2016). Qualitative inquiry & research design : choosing among five approaches. Sage Publications, Inc PP - Thousand Oaks.

Dirhamsyah, D., Yusnida, Y., & Gukguk, Y. R. (2024). Penerapan Inaportnet Dalam Proses Pelayanan Kapal Dan Barang (Ppkb) Di Pelabuhan Pada Pt. Salam Pacific Indonesia Lines Cabang Belawan. Journal of Maritime and Education (JME), 6(1), 608–613. https://doi.org/10.54196/jme.v6i1.127

Edwards, G. C. (1980). Implementing Public Policy. Congressional Quarterly Press.

Efansyah, A., & Basuki, M. (2021). Model Pengelolahan Air Balas Kapal Akibat Deballasting Di Pelabuhan Peti Kemas Surabaya Menggunakan Metode Bow Tie Risk Assessment. Prosiding Seminar Teknologi Kebumian Dan Kelautan, 3(1), 232–236. https://doi.org/10.31284/p.semitan.2021.1970

Farhan, A., Lauren, C. C., & Fuzain, N. A. (2023). Analisis Faktor Pencemaran Air dan Dampak Pola Konsumsi Masyarakat di Indonesia. Jurnal Hukum Dan HAM Wara Sains, 2(12), 1095–1103. https://doi.org/10.58812/jhhws.v2i12.803

Fauzan, F., & Milantara, N. (2024). Dampak Aktivitas Antropogenik Terhadap Keanekaragaman Amfibi Di Daerah Aliran Sungai Batang Kuranji Kota Padang. Menara Ilmu/Menara Ilmu, 18(1). https://doi.org/10.31869/mi.v18i1.4867

Hanafi, S., Djabbar, Y., Fahri, M., Jasmin, S. P., & Zulhidayat, M. (2023). Tantangan dalam Implementasi Kebijakan Perlindungan Hak Asasi Manusia bagi Penyandang Disabilitas di Provinsi DKI Jakarta. Jurnal Hukum Dan HAM Wara Sains/Jurnal Hukum Dan HAM Wara Sains, 2(6). https://doi.org/10.58812/jhhws.v2i6.446

Iqbal Khan, T., Kaewsaeng-on, R., Hassan Zia, M., Ahmed, S., & Khan, A. Z. (2020). Perceived organizational politics and age, interactive effects on job outcomes. SAGE Open, 10(3), 2158244020936989.

Irawanto, R., & Afifudin, A. F. M. (2022). Fitoremediasi model "COWEST" dalam Pengelolaan Kualitas Air di Bumiaji - Batu, Jawa Timur. I-Com: Indonesian Community Journal, 2(3), 550–557. https://doi.org/10.33379/icom.v2i3.1825

Jamil, R. A., Qayyum, U., ul Hassan, S. R., & Khan, T. I. (2023). Impact of social media influencers on consumers' well-being and purchase intention: a TikTok perspective. European Journal of Management and Business Economics, (ahead-of-print).

Khan, F. A. J. T. I., Anwar, F., Sheikh, R. A., & Kaur, S. (2012). Neuroticism and job outcomes: Mediating effects of perceived organizational politics. African Journal of Business Management, 6(7), 2508.

Khan, M. T., Khan, T. I., & Khan, S. (2020). Innovation & Its Diffusion in Business: Concept, Stages & Procedural Practices. sjesr, 3(4), 174-186.

Khan, T. I., & Akbar, A. (2014). Job involvement-predictor of job satisfaction and job performance-evidence from Pakistan. World Applied Sciences Journal, 30(30), 8-14.

Khan, T. I., & Akbar, A. (2015). Impact of stressors on employee performance: Moderating role of big five traits. Islamabad: Mohammad Ali Jinnah University.

Khan, T. I., Akbar, A., Jam, F. A., & Saeed, M. M. (2016). A time-lagged study of the relationship between big five personality and ethical ideology. Ethics & Behavior, 26(6), 488-506.

Khan, T. I., Kaewsaeng-on, R., & Saeed, I. (2019). Impact of workload on innovative performance: Moderating role of extrovert. Humanities & Social Sciences Reviews, 7(5), 123-133.

Khan, T. I., Kaewsaeng-On, R., & Saeed, I. (2019). Impact of workload on innovative performance: Moderating role of extrovert. Humanities & Social Sciences Reviews, 7 (5), 123-133.

Khan, T. I., Khan, A. Z., & Khan, S. (2019). Effect of time pressure on organizational citizenship behavior: Moderating role of agreeableness. Sir Syed Journal of Education and Social Research (SJESR), 2(1), 140-156.

Khan, T. I., Khan, S., & Zia, M. H. (2019). Impact of personality traits on workplace deviance–a pakistani perspective. Global Regional Review, Humanity only, 4(2), 85-92.

Khan, T. I., Nisar, H. G., Bashir, T., & Ahmed, B. (2018). Impact of aversive leadership on job outcomes: Moderation and mediation model. NICE Research Journal, 56-73.

Kuo, Y. K., Khan, T. I., Islam, S. U., Abdullah, F. Z., Pradana, M., & Kaewsaeng-On, R. (2022). Impact of green HRM practices on environmental performance: The mediating role of green innovation. Frontiers in Psychology, 13, 916723.

Kuo, Y. K., Khan, T. I., Islam, S. U., Abdullah, F. Z., Pradana, M., & Kaewsaeng-On, R. (2022). Impact of green HRM practices on environmental performance: The mediating role of green innovation. Frontiers in Psychology, 13, 916723.

Li, H. X., Hassan, K., Malik, H. A., Anuar, M. M., Khan, T. I., & Yaacob, M. R. (2022). Impulsive and compulsive buying tendencies and consumer resistance to digital innovations: the moderating role of perceived threat of COVID-19. Frontiers in Psychology, 13, 912051.

Mulyadi, A., & Atmaja, E. S. (2016). Dampak Pencemaran Waduk Saguling Terhadap Budidaya Ikan Jaring Terapung. Jurnal Geografi GEA, 11(2). https://doi.org/10.17509/gea.v11i2.1622

Mushtaq, R., Jabeen, R., Begum, S., Khan, A., & Khan, T. (2021). Expanded job scope model and turnover intentions: A moderated mediation model of Core-Self Evaluation and job involvement. Management Science Letters, 11(5), 1473-1480.

Mutia UPT. Perpustakaan Unand, J. M. P. P.-D. dissertation. (2015). Penertiban Travel Liar Dalam Pelayanan Transportasi Publik Di Kabupaten Pesisir Selatan.

Nursyamsu, N., Putra, A. M., Dewi, A. K., & Sutryani, H. (2022). Pengaruh Pengetahuan, Pengawasan dan Kelengkapan Sarana Pengelolaan Sampah Awak Kapal terhadap Perilaku Pencegahan Pencemaran Laut di Pelabuhan. Quantum Teknika, 4(1), 13–20. https://doi.org/10.18196/jqt.v4i1.15696

Oginah, S. A., Posthuma, L., Hauschild, M., Slootweg, J., Kosnik, M., & Fantke, P. (2023). To Split or Not to Split: Characterizing Chemical Pollution Impacts in Aquatic Ecosystems with Species Sensitivity Distributions for Specific Taxonomic Groups. Environmental Science & Technology, 57(39), 14526–14538. https://doi.org/10.1021/acs.est.3c04968

Parwati, N. P. Y., Putra, N. Y. N., Arsana, I. K. Y. A., & Mahadewi, N. P. R. (2024). Pertumbuhan Dan Perkembangan Kota-Kota Pelabuhan. Nirwasita, 5(1), 88–94. https://doi.org/10.59672/nirwasita.v5i1.3624

Ridho, H., Thamrin, M. H., Nasution, F. A., & Indainanto, Y. I. (2023). Disposition of Waste Management Policy Implementers Through the Regional Cooperation Scheme. International Journal of Sustainable Development and Planning, 18(1), 275–282. https://doi.org/10.18280/ijsdp.180129

Sadri, E., Harsej, F., Hajiaghaei-Keshteli, M., & Siyahbalaii, J. (2021). Evaluation of the components of intelligence and greenness in Iranian ports based on network data envelopment analysis (DEA) approach. Journal of Modelling in Management, 17(3), 1008–1027. https://doi.org/10.1108/jm2-03-2021-0071

Salsabila, A. S., & Basyaiban, M. K. (2022). Pencemaran Sungai Musi dan Upaya Penanganannya di Sumatera Selatan Tahun 2007-2021. Environmental Pollution Journal, 2(3). https://doi.org/10.58954/epj.v3i3.89

Samdara, R. (2017). Laju Perubahan Muka Air Laut Di Wilayah Perairan Pantai Bengkulu Dengan Menggunakan Satelit Altimetry. Jurnal Fisika Flux/Jurnal Fisika Flux, 11(2), 197–203. https://doi.org/10.20527/flux.v11i2.2682

Sarwat, N., Ali, R., & Khan, T. I. (2021). Challenging, hindering job demands and psychological well-being: The mediating role of stress-related presenteeism. Research Journal of Social Sciences and Economics Review, 2(1), 135-143.

Sudaryanti, S., Mahmudi, M., Musa, M., & Darmawan, A. (2023). Model Manajemen Sumber Daya Perairan Waduk Serbaguna. Universitas Brawijaya Press.

Sumudumali, R. G. I., & Jayawardana, J. M. C. K. (2021). A Review of Biological Monitoring of Aquatic Ecosystems Approaches: with Special Reference to Macroinvertebrates and Pesticide Pollution. Environmental Management, 67(2), 263–276. https://doi.org/10.1007/s00267-020-01423-0

Thamrin, M. H., Ridho, H., & Nasution, F. A. (2022). Strengthening Community Participation in Spatial Planning of Riverflow Regions in Medan City. International Journal of Sustainable Development and Planning, 17(6), 1849–1854. https://doi.org/10.18280/ijsdp.170619