Artificial Intelligence and Decision Support System to Determine Policies for Controlling River Pollution from Industrial Sectors

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Abstract: One of the principal difficulties faced in developing countries is poor water quality. Approximately 90% households and industrial wastes are discharged untreated properly, directly into the ground and surface water. This research aims to analyze the use of artificial intelligence as a decision support system (DSS) to monitor and determine policies for controlling river pollution from industrial sectors. This study uses an interpretive approach or a qualitative approach by implementing the library research method. Integrated river basin management involves all management issues associated with the supply, use, rehabilitation, protection, pollution, and many others in a river basin. In the decision-making process, it considers the relations between the abiotic and the biotic part of the various water systems, between the ecological and economic factors, and between the various stakeholder interests. The use of technology by policymakers is important to address these water quality-related challenges. Therefore, DSS as an artificial intelligence tool is required to carry out river basin management processes. Thus, water managers can make policies and decisions on the implementation of measures to improve the quality of surface water in the river faster and more precise.

Keywords: Artificial Intelligence, Policy, River Pollution

1. Introduction
1.1 River Water Pollution

Water resources policymakers require the development of proper quantities with an adequate quality of water as populations grow and climate varies in many developing countries. In general, water covers 71% of the earth’s surface. However, 97% of the earth's water is found in the oceans (too salty for drinking, growing crops, and most industrial values except cooling). Nevertheless, 3% of the earth's water is fresh but 2.5% of them are unavailable (locked up in glaciers, polar ice caps, atmosphere, and soil; highly polluted; or lies too far under the earth's surface to be extracted at an affordable cost). Therefore, freshwater that is available is only 0.5% of the earth’s water [1]. The water demand continues to increase as the population and industry grow. Cities cannot be sustainable without assuring reliable access to safe drinking water and adequate sanitation. Water problems include various fields, including depletion of aquifers, siltation of dams, salinization of irrigation water, flooding, prolonged drought, and contamination of ground and surface water. A surface water resource quality indicates all natural and anthropogenic activities that occur within the watershed and river basin. However, climate, topography, hydrology, soils, agricultural practices, and other human activities affect the water quality within a watershed [2].

Although natural factors affect water quality, it is most often the anthropogenic activities that pollute water resources. Industrialization and urbanization have put further strain on the nation’s water
resources due to water quality degradation [3]. In many developing countries, wastewater is treated inadequately before being released to the environment. It brings negative consequences for human health, economic productivity, the quality of freshwater resources, and ecosystems. In many cases, a large volume of the wastewater that is legally discharged to decaying and/or poorly-maintained sewerage networks, either combined and separate, never actually reaches a treatment plant [4]. In Surabaya for example, the heavy pollution in the Surabaya River as the source of drinking water is worsening the quality of drinking water. The pollution arose from the dozens of factories throughout the Surabaya River, as well as from household waste [5]. The pollution load originating from industry, domestic and agriculture is 55.49 tons BOD/day), COD 132.58 tons COD/day), exceeding the pollution load carrying capacity (DTBP) of 29.86 tons BOD/day and 40.45 tons COD/day [6]. Similar conditions occur in the Citarum River. The pollution in the Citarum river has become the world's spotlight as one of the 10 most polluted rivers in the world [7]. The factors that hold a high level of BOD along the Citarum watershed are the disposal of waste by industries. The impact of industrial wastewater on the water quality in Citarum River can be seen from the increasing number of organic matter content (BOD) and the decreasing number of dissolved oxygen (DO) from upstream to downstream after passing the industrial zone [7].

1.2 Decision Support System for River Water Quality Management

Water quality management is the devising for the water quality protection, various beneficial uses, provision of adequate wastewater collection, treatment, disposal for municipalities and industries, activities that might create water quality problems, regulating and enforcing programs to accomplish the planning goals, laws and regulations dealing with water pollution control. Thus, water quality management is a very complicated task concerning hydrology, hydrodynamics, pollution load, and water quality, which requires the consideration of a wide scope of social, economic, and environmental aspects [8]. It is necessary to first determine its status and then devise a protection or remediation plan to improve or protect water quality. At the technical level, watershed management includes assessing and evaluating the water quality problem, defining the critical area(s) or sources(s) within the watershed (the area(s) that contribute the majority of the pollutant(s) to the water resource), and designing a pollution control program.

The common procedure for analyzing the water quality data and determining its status is regularly carried out by comparing the concentration of the on-site measured parameters and their relative standard. This procedure does not describe the overall water quality in a way that can be done easily. Furthermore, to conduct this process, it takes a long time, effort, and specialist. Therefore, a Decision Support System (DSS) is necessary to carry out this process. A DSS is defined as an interactive, flexible, and adaptable computer-based information system, specially developed for supporting the solution of a non-structured management problem for improved decision-making [9]. A DSS can be used to support both strategic and operational decision-making in water management. DSS is a very valuable process for stakeholders involved in water management. Numerous elements can affect water quality, water scarcity, and the long-term health of environmental assets. A DSS process enables users to examine any potential scenario before making determinations that will ultimately impact real assets and people. This is one of the safest and most cautious methods to control water management while assuring all determinations are based on carefully explored knowledge, history, and potential risks.
2. Method

This study uses an interpretive approach or a qualitative approach by applying the library research method. Library research is a study that emphasizes literature as an object of study. In this research, it is carried out by examining the ideas of experts, existing conceptions, and the regulations related to the object of science [10]. This study is intended to analyze the use of artificial intelligence as a decision support system to monitor and determine policies for controlling river pollution from industrial waste. This research's steps are data collection, coding, temporary conclusions, triangulation, and final conclusions. The raw data collection is obtained through documentation study by recording raw data without the intervention of thoughts, comments, and attitudes of researchers. The coding will record important data, keywords, and determining codes.

3. Basic Theory

3.1 Artificial Intelligence (AI) and Decision Support System

Decision making is an essentially human activity that can create significant impacts. It is reasonably expected that researchers have attempted to enhance the quality of decisions by developing computer technologies to augment and extend human capabilities. Advances in Artificial Intelligence (AI) have created this goal a reality in various applications. Nowadays, most definitions state that AI solves complex cognitive problems correlated with human intelligence, or that AI supports as many people as possible through smartphones or healthcare, or indeed AI identifies problems and creates solutions for technology, people, and society [11]. Nevertheless, the core concept of AI has continually been to create machines that we're able to think like humans AI-integrated decision-making support systems, or intelligent decision support systems (DSS) for short, are progressively utilized to assist in deciding on several areas such as finance, healthcare, marketing, commerce, command and control, and cybersecurity [12]. AI has been also applied to environmental management problems, for example, in using expert systems to deal with industrial waste recovery network optimization [13], water demand modeling [14], measuring traffic air pollution [15], climate change simulation [16], environmental quality analysis [17], and many other applications for sustainable development (water, agriculture, sanitation) [11]. A Decision Support System (DSS) can be applied to assist managers on various management levels, obtaining a better (or more efficient) decisions, also stimulate them in taking effective measures. An effective decision should at once be reasonable, justifiable, and legally and morally correct in the particular context of environmental management.

3.2 DSS for policy planning and implementation

Environmental protection and water quality management have become an important issue in public policies throughout the world [18]. More than governments are concerned about the quality of their environmental resources because of the complexity of water quality data sets [19]. It is necessary to examine the cycle of policy planning and implementation to understand how DSS tools support river managers (Fig. 1). The policy cycle consists of six steps [20](Hoekstra, 2005), which take place iteratively rather than sequentially. A key activity in the planning phase, aimed to identify and analyze management alternatives, is the policy analysis. It requires scientific knowledge and expertise to explain the effects of different combinations of measures and scenarios on selected indicators. It is important to gain support for a policy during the implementation phase [21]. However, this conceptual model of control leaves the question open to what extent and how a DSS can support river basin managers. The information and support role for effective control in water management can be formulated in three conditions. Consistency refers to a rational problem-solving process, which concerns the planning cycle in Fig. 1, aimed to formulate clear objectives and actions to achieve the goals. Nevertheless, the complexity of integrated
river basin management is also a consequence of the different necessity that possibly contradicting. Therefore, the second condition for a management plan to be implemented effectively is gaining supports. The third condition is the supply of information, both the formulation of a consistent management strategy and the creation of support benefit from adequate information.

Figure 1 The Policy Cycle[20], [21]

4. Findings and Discussion

4.1 DSS for Sustainable River Basin Management

To support the decisions to be made in the water utilization and management aspects, a river basin planning DSS is required. The DSS should be able to describe the behavior of a complex river basin including its appearance over time, response to natural phenomena, and impacts of measures to mitigate undesired responses to enable selection of optimal measures in terms of performance [22]. Ideal decision instruments for soil, water, and environmental management must incorporate quantitative and analytical components linked to the system. Dinar [23] states that river basin models are interactive programs using analytical methods, such as simulation and optimization algorithms, to assist decision-makers in formulating water resources alternatives, analyze their impacts, and interpret and select appropriate options to implement. It uses models to simulate water resource system behavior based on a set of rules governing water allocations and infrastructure operation. Also, it utilizes models to optimize water resource system behavior based on an objective function and accompanying constraints. Models tend to reduce the time for decision making in these uses. It might improve the consistency and quality of those decisions. Furthermore, models are needed by negotiators, planners, and managers of water resource systems, as well as other stakeholders who may be concerned about the economic or environmental uses of shared water resources in the context of transboundary river basins. One of the objectives of these decision-makers is to implement a steady supply of water with appropriate quality, production of hydropower, protection from floods and ecosystems. In transboundary basins, the water allocation to numerous users and sectors is carried out following the prevailing institutional structure of water rights according to national laws, basin-wide negotiated agreements, and international laws.

Fig. 2 is the illustration of the DSS Framework for the application of a river basin model [23]. River basin modeling requires, in various degrees depending on the problem that is under consideration, these following activities:

- Data Measurement and Collection – receipt of various data (e.g., water level and temperature, precipitation, air temperature, concentrations, water quality, etc.) from stations throughout a river basin. Also, several economic and social data are measured and collected.
Data Processing – storage and process data related to the processes of interest in the basin, both spatial features as well as time-series data. In this context, it uses a relational database to store the measured data. A data model is used to organize the data in the database according to the “basin” principle, and a geographic information system is used to display the data graphically;

Analytical Tools – models designed to predict basin response to various climate and development scenarios;

Decision Formulation and Selection – the utilization of results from the models and interaction with users to make decisions on water management in the basin; and

Decision Implementation – dissemination of decisions regarding water use under various conditions.

4.2 Water quality monitoring and real-time management

Monitoring adequate river quality is a major importance for riverine environmental sustainability. Water quality monitoring network design could be a fairly complicated problem. There are some questions to determine such as the number of gages required, frequencies of sampling, and benefits over cost ratio of monitoring. These issues are in the case of river water quality sampling variables, as they are more error-prone, high-priced, and time-consuming. The primary difficulty underlying the monitoring systems’ design and evaluation is the lack of an objective measure to assess the efficiency and the cost-effectiveness of the monitoring network [24].

4.3 Policy for Sustainable River Basin Management

In general river basin management, policy decision-makers confronted with problems, including pollution control plans for river basins and estuaries development, hydrodynamic and water quality impacts of alternative control strategies; design and operation of wastewater treatment plants, i.e., level of treatment that is necessary to meet water quality goals under specific flow conditions; and management of river basins, including the evaluation of the interrelationships between economic productivity and environmental degradation in a basin [23]. A river basin is generated by the redundancy, a socially constructed process for expanding water capacity, mainly for irrigation, households, and industry. The process is fundamentally driven by the vested interests of politicians, water bureaucrats, private construction firms, development banks, and the powerful incentives they face in sustaining water resources development. Also, overbuilding is caused by regional politics and equity issues, where
differences in relative wealth between regions are used by poorer ones to claim for hydraulic (and other) investments even if hydrologic and economic conditions should discourage them. In other settings, between federal states/districts, it is commonplace to see a rush toward infrastructure development to claim or support a prior claim on the shared resource. Supply augmentation is more attractive to decision-makers because they can avoid politically costly reductions in employment or reallocation, but are often adopted at the expense of the public purse and environment preservation [25].

River basin organization (RBO) must take a leading role to manage and take policies towards sustainable watershed management to have sustainable river basin management. RBO should have a very broad mandate on basin policy and management including agencies, committees, commissions, authorities, associations, administrations, directorates, councils, hydraulic confederations, boards, and trusts. From a governance point of view, RBO can be typified, first, by its vertical integration within the state administration and, second, by its horizontal integration with non-state actors. RBO must become a leading role to define the rules of the game including water rights, user fees, and water quality standards in different sectors, users, and governmental agencies involved. In this context, water managers have to make decisions on the measures implemented to improve the quality of surface water in the river.

5. Conclusion

Water quality issues are continuously becoming more complex and diverse. The handling of these issues requires an increasing amount of specific knowledge. In addition, this also requires more efficient integration across various disciplines, sectors, countries/districts, institutions, cultures, actors, and societies. Therefore, there is a need for a DSS as an artificial intelligence tool to carry out the river basin management process. According to Dinar [23], the DSS Framework for the application of a river basin model consists of the following five activities: data measurement and collection; data processing; analytical tools; decision formulation and selection; and decision implementation. Decision-makers should understand critical water management aspects in the basin the model should represent: the underlying physical processes; the institutions and rules that govern the flows of water and pollutants in the basin; the water diversion, use and return sites in the basin, including consumptive use locations for agricultural, municipal, industrial, and in-stream water uses (incorporating also reservoirs and aquifers); and the economic benefits of water-use by applying production and benefits functions for water for use in the agricultural, environmental, urban, and industrial sectors. RBO may be responsible for any combination of tasks that include maintenance, construction, management of infrastructures, development of basin masterplans, allocating water or administrating rights, monitoring and collecting hydrologic or water quality data, fee collection and promotion of public participation, law enforcement on river pollution base on real-time information, and fast analysis DSS model by using artificial intelligence.

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