International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 02 Issue: 12 December 2025
Page No: 4240-4247
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2025.0621

Digital Water Treatment Process Designer

G Hasumathi Lakshmi[1], B Lakshitha[2], M Divya Sri[3], V Divya Darshini[4], M Ahsan Shariff[5]
[1,2,3,4,5]Department of MTech Computer Science and Engineering (5 years integrated), Sri Sai Ram Engineering College, Sai Leo Nagar, West Tambaram, India.
Emails: *hasumathilakshmi@gmail.com1, lakshithabaskar05@gmail.com[2], dsri09102004@gmail.com[3], divyadarshini2881@gmail.com[4], ahsan.cj@sairamtap.edu.in[5]*

Abstract
Many of the environmental problems are caused by industrial effluents. They create many more problems aside from contaminating the air, water and living organisms. By abusing the water and letting it flow into already present bodies of water and land, they also add a lot to the public's health issues and diseases. Poorly engineered plants will not contain the essential components or may not address certain contaminants in the water source. In addition, choosing the chemicals employed during water treatment is essential for the process to succeed. The paper intends to introduce the fundamental concept of a software that can offer flow charts illustrating the treatment process sequence, diagrammatical illustrations of the equipment with design and capacity requirements and the total cost of the treatment plant installation that is needed in the treatment of domestic and industrial wastewater.

Keywords: *Industrial Effluents, Diagrammatic Representations, Specification.*

1. Introduction
The design of a water treatment system will depend on water quality, regulatory requirements, customer/environmental concerns, construction layout, operational limitations, MedTech technology, and business potential [1]. Wastewater treatment refers to the removal of impurities in wastewater or sewage before it is released into the water body. Domestic, commercial and restaurant water use. Wastewater consists of discharges from manufacturing and chemical industries. [3] The estimated volume of wastewater produced by households, businesses, and industries associated with sewer systems, together with expected inflow and infiltration (I&I), determines the size and capacity of wastewater treatment plants. Many factors such as the number of customers, geographical region, limited space, pipe connections, average and maximum, characteristics of incoming wastewater, wastewater management, efficiency, energy efficiency, operation and maintenance costs will specifically affect its choice. -site, cluster or centralized treatment configurations. Wastewater can be characterized by some negative properties, including oxygen, acidity, chlorine, etc.[2] Currently, 380 billion cubic meters of wastewater are produced annually worldwide. There are many examples of such closed sewage treatment plants. Selection of appropriate information, such as mathematics and simulation, can help in the decision-making process [4]. The software evaluates the properties of water and pollutants, determines the usage plan, makes recommendations on equipment and capacity. Number of procedures, drawings and total cost. This involves developing clinical design tools, simulating various scenarios, reviewing performance metrics, and recommending improvements. The main purpose of the software is to help engineers, environmental professionals, and people affected by wastewater manage and improve their wastewater processes by providing data-driven insights and the ability to succeed. The application aims to simplify the design, operation and maintenance of wastewater treatment systems and promote sustainable water treatment and a better environment.

2. Literature Survey
The initial research focuses on how DSS helps combine environmental, economic as well as social considerations, presenting a total picture that

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enhances decision-making effectiveness to respond to the intricacies of water management problems. It aids in formulating well-balanced and sustainable solutions based on long-term effects and the interests of various stakeholders [5]. The optimization of water treatment processes incorporates the use of mathematical programming and simulation methods. The article has highlighted the importance of effective resource allocation and cost-effectiveness in decision-making and demonstrated the role played by DSS in facilitating operationalization of sustainable water management by balancing multiple operating and economic considerations[6].In their article, "Multi Criteria Analysis for Sustainable Water Resources Planning: A Case Study," Raju and Duckstein (2004) describe the application of Decision Support Systems (DSS) for comparing different water treatment alternatives. They emphasize the use of multicriteria decision-making (MCDM) techniques in DSS to evaluate and rank various water management strategies according to technical, economic, and environmental considerations. This would allow leveraging a broader evaluation, transcending the dimensions of cost-effectiveness, resource saving, and environmental sustainability. The article includes an example illustrating the applicability of these tools to real instances of water resource planning [7]. Hajkowicz (2008) undertakes a review of literature on alternative Decision Support Systems (DSS) used in sustainable water management. The author focuses on the importance of accurate and comprehensive data in enhancing reliable decision-making systems. Besides other aspects, the article highlights the way DSS can assist in meshing different aims of conservation, economic efficiency and social justice towards a systematic solution of complex water management issues [8].

3. Methodology

The software development is set to create a dynamic and interactive user interface using React.js that will allow users to enter water quality details, treatment objectives, while containing accompanying diagrams and cost estimates. The backend shall be created through Node.js with Express which will perform server-side functions like data processing including input parameters analysis for choosing right treatment methods and making graphs as well as queries handling from the API. In managing structured data, MongoDB will be utilized for database system where it maintains tables of water treatment processes, equipment pieces, and budget templates. Cadd software is going to be used to generate/draw elaborate process flow diagrams and equipment drawings so as to encourage users in investigating the different treatments that can be customized. Custom algorithms will also be programmed for cost estimation that will incorporate machinery needs and chemical usage rates along with operational factors which are given in customizable budgets tables. For example, the outputs from this software include process flow diagrams, equipment diagrams detailed budget estimates, chemical specification file, real-time API responses, data analytics reports etc. Furthermore, metrics such as response time and scalability would be measured to ensure efficiency and robustness during operation of the software system, shown in Figure 1.

Figure 1 Diagram

3.1. Requirements Gathering

To understand the needs of potential users, we conducted interviews and surveys with water treatment engineers, consultants and industry experts. Key requirements identified are:

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- Parameters needed for designing water treatment processes.
- Types of diagrams and machinery details required.
- Budgeting criteria and cost factors in water treatment.

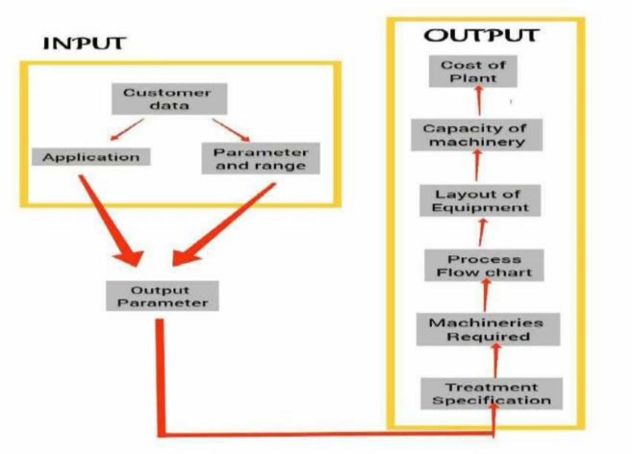

Figure 2 Process Flow Diagram

3.2. Application Architecture

The application was designed with the following components:

- **User Interface:** A web-based form for users to input chemical parameters, impurity levels and treatment goals. A dashboard displays generated diagrams and budget estimates.
- **Backend Logic:** Processes the input data to determine suitable treatment methods and generate relevant diagrams and estimates.
- **Database:** Stores data related to treatment processes, machinery and budget information.
- **Diagram Generation:** Utilizes Cadd for creating process flow diagrams and machinery diagrams based on user inputs.
- **Budget Calculation:** Algorithms estimate costs by analysing machinery requirements, chemical usage and operational factors.[9]

4. Implementation

4.1. Frontend Development

Frontend HTML5 [10] utilizes CSS3[11] for styling and layout, and it supports multimedia and graphical content natively for organizing the contents of web pages. React.js facilitates the creation of reusable user interface components, supports dynamic websites and offers a responsive user experience when used to build web applications' user interfaces. Web pages that prioritize mobile devices and are responsive are made using the Apache UI framework. To expedite development, it offers responsive grid systems, utilities and pre-styled components.

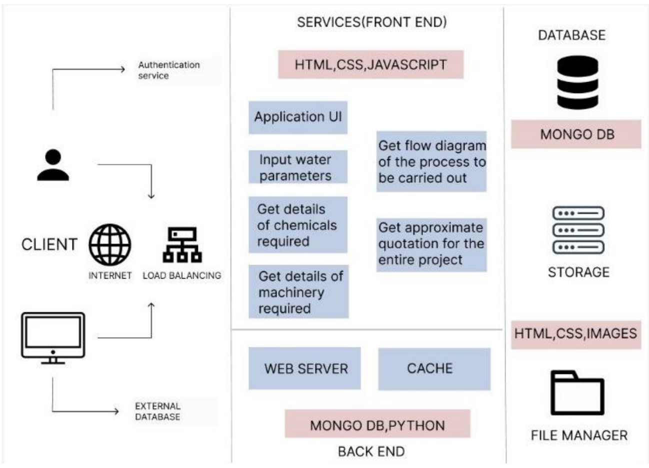

Figure 3 Architecture Diagram

4.2. Backend Development

Node.js with Express can be used to handle server-side operations. This included data processing for analyzing input parameters to select appropriate treatment methods and generate diagrams as well as API management to handle requests from the frontend and deliver responses with the required data.[12] Python and Java are used in the software's backend to take advantage of their distinct benefits. Python is used because of its robust library ecosystem, ease of use and strong data processing, API integration and task management capabilities. These capabilities are crucial for managing the logic found in wastewater treatment processes.[13] Java, on the other hand, is preferred for building high-performance backend services that call for effective processing of big datasets and high concurrency due to its robustness, performance and scalability. The program can efficiently handle intricate computations, produce flow charts and diagrams and guarantee dependable and scalable performance by combining Python and Java. This gives it a complete solution for wastewater treatment plant design and cost estimation, shown in Figure 2 & 3.[14]

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4.3. Database Setup

MongoDb can be used to manage structured data with a schema that includes a Processes Table to store details about different water treatment processes, a Machinery Table containing information on machinery and equipment used in treatment processes and a Budgets Table to maintain budget templates and cost factors for various treatment scenarios, shown in Figure 4 & 5.

5. Outcomes

5.1. Process Flow Diagrams

The software offers detailed graphical illustrations of the steps taken in order during the water treatment process. The process flow diagrams are user-defined, and therefore the user is able to modify and customize the treatment process to meet particular requirements and specifications. The extent of flexibility ensures that the diagrams accurately represent the unique needs of each treatment plant to the last detail, enabling proper planning and execution.

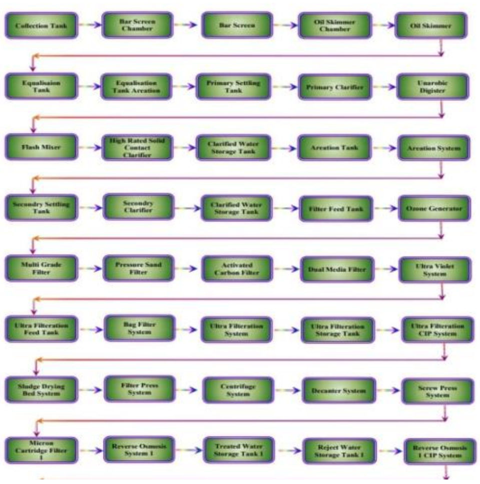

Figure 4 Machinery Along with Flow Diagram

5.2. Equipment Diagrams

Diagrammatic designs of the equipment employed in each phase of the treatment process constitute another key output of the software. The diagrams contain design details and capacity information for each piece of equipment, thus enabling appropriate selection and integration within the treatment plant. Through the provision of correct and accurate equipment drawings, the software enables users to make informed decisions regarding machinery to be employed within their individual treatment processes.

5.3. Budget Estimates

The software gives elaborate cost estimates of the installation and functioning of water treatment plants. The cost includes machinery, chemicals, man power, and other operational costs. The software also gives editable budget templates, which can be edited as per specific situations and needs. With this complete financial planning tool, the user can stretch his/her budget to its maximum utilization and allocate the resources in a meaningful manner.

5.4. Data Analysis Reports

Such detailed analysis of input parameters is furnished to facilitate suitable selection of treatment processes. The software produces reports from the input water quality data and treatment objectives, emphasizing the suitability and efficiency of various treatment processes. These reports provide useful information pertaining to the best direction of treatment so that the chosen processes are best suited for the given needs and conditions of the source water.

5.5. Chemical Specifications and Quantities

The software provides accurate data on types and amounts of chemicals needed in water treatment. It provides specifications of each chemical in terms of concentration and usage rates, and these are specifically designed for target water pollutants. The users can therefore choose proper chemicals in the right amounts, maximizing the treatment process while avoiding undesirable effects due to improper usage of chemicals.

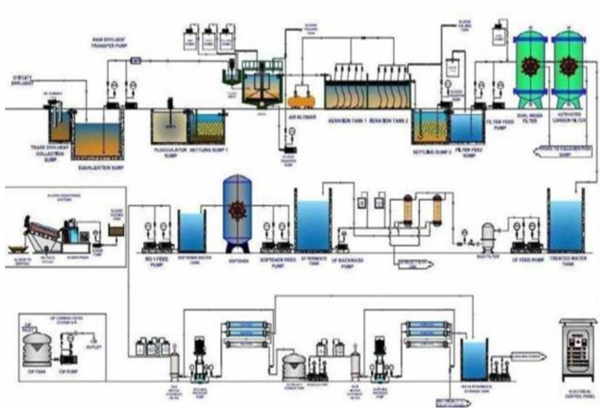

Figure 5 Machinery Along with Flow Diagram

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6. Module Description

6.1. Home Module

The Home Module acts as the homepage of the website and plays an important role in giving a good introduction to the project and what it is all about. In fact, the Home Module clearly lays out to the user how the water treatment solution works and allows for easy navigation to other important modules to register or set parameters. Along with this, the Home Module contains information to help users understand the system benefits and purpose in a simple and engaging way. This section of the website also has visual elements (banners) to engage the users attention and make the platform visually appealing. Overall, the Home Module is supposed to allow the first-time user to quickly understand what the platform is and easily guide them into the design process.

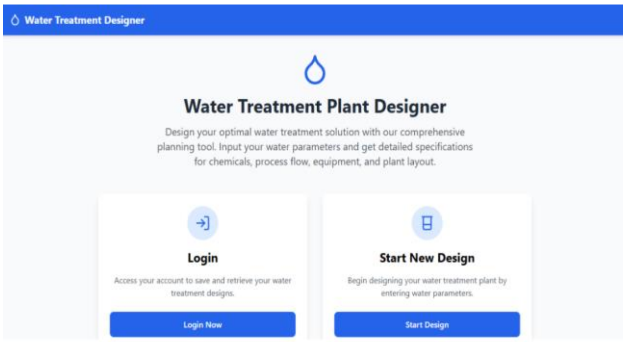

Figure 6 Home Page

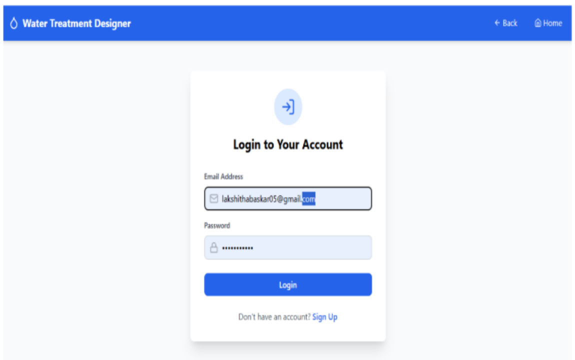

Figure 7 Login Page

6.2. Login Module

The Login Module is crucial to the system, allowing only the logged in users to access the above functionality. The module ensures a secure log in through user email and password, along with validation and handling of any errors if the user makes a mistake during authentication. The Login Module authenticated user, while managing user sessions to keep their activities secure and uninterrupted. Overall, the Login Module is intended for providing safe and secure access to a personalized aspect of the platform including, data input, viewing recommendations, generating reporting, and overall experience through the recommended experience.

6.3. Parameter Input Module

The Parameter Input Module allows users to log important information from lab tests which define the characteristics of the water. Users can provide values for key parameters including pH, total dissolved solids (TDS), turbidity, and hardness. The software will compare each value with standard acceptable ranges, and will immediately alert the user if a value falls outside of acceptable limits. The Parameter Input Module is important because it captures the information needed to determine the appropriate treatment process and chemicals needed.

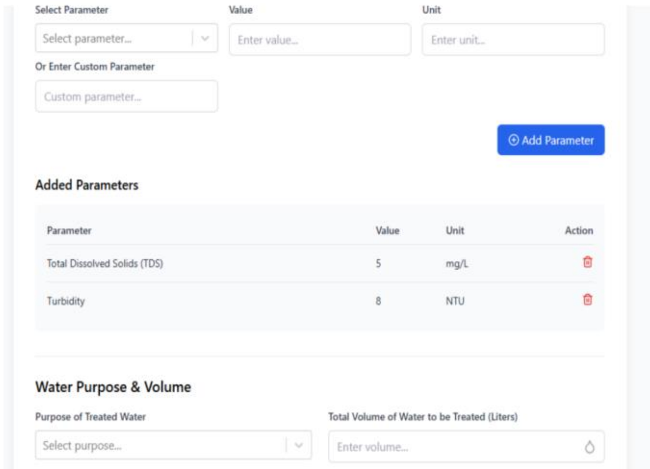

Figure 8 Parameter Input Module

6.4. Chemical Recommendation Module

The Chemical Recommendation Module evaluates the water quality parameters provided by the user, and then provides a recommendation for the most appropriate treatment chemicals. It processes the values inputted into the system and determines the recommended treatment type, and amount; for example, a coagulant or disinfectant, and then includes a clear explanation of the rationale for each treatment chemical recommendation. The goal of the Treatment Chemical Advisor Module is to promote an easier and efficient chemical selection process. It is important to note that the goal of the module is to support the process of selecting treatment chemicals based on science, and with accurate data.

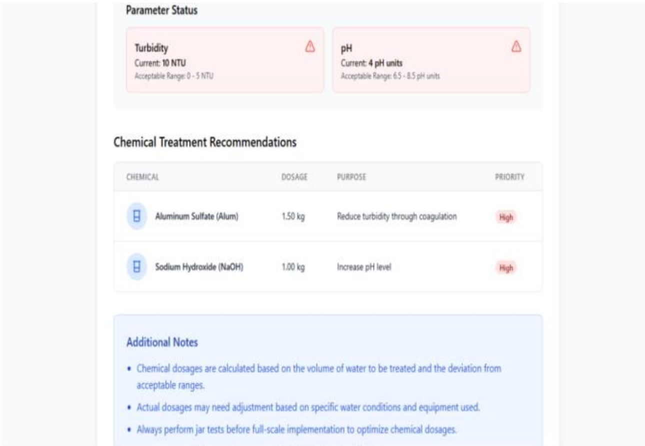

Figure 9 Chemical Recommendation Module

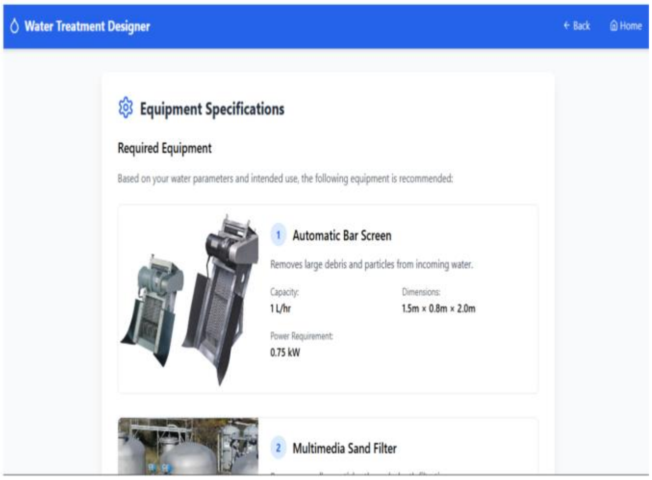

Figure 10 Chemical Recommendation Module

6.5. Equipment Specification Module

The Equipment Specification Module makes product recommendations for the treatment process, along with detailed specification. The module provides a full list of equipment that will include tanks, filters and dosing pumps, as well as effectiveness specifications, such as capacity, dimensions, materials, and quantity. Additionally, the module estimates the cost for each item, allowing the user to have a clearer picture of the overall amount of investment needed. This module ultimately provides guidance to the user on hardware selection to successfully set up and efficiently operate a treatment plant at the most practical and cost-effective level.

7. Experimental Setup

7.1. System Implementation

The water treatment application is a web-based application geared towards users such as environmental engineers, scientists, and water treatment consultants that enables them to review an appropriate treatment method. The application allows users to enter a few basic water quality parameters such as pH, turbidity, total dissolved solids (TDS), hardness, and iron concentration. After entering the parameters, the application can generate analytical information and visualizations that will help the decision-making process. The visualizations could either be based on the recommended treatment methods or 2D and 3D interactive visualizations, in addition to estimated costs and process flow diagrams that describe the stages of treatment. The application is built to run on modern web browsers; development was performed in Visual Studio Code on Windows 11. The application is served through a Vite development server, which helps module hot replacement creating a simplified development experience, and the viewer user experience is real-time during testing and debugging, shown in Figure 6 & 10.

7.2. System Design

In our Water Treatment Process Designer project, we have added advanced technology, Reality Capture . We captured high-resolution images of real-world equipment, then processed those images in Reality Capture software with it, producing 3D representations of design elements such as coagulation and flocculation tanks, sedimentation basins, filtration systems, aeration systems, chlorination systems, sludge drying beds, pumps, and control panels, all in photorealistic detail. These 3D assets were optimized to support real-time interaction and integrated directly into the designer software so that users could explore and interact with the pieces of equipment from every angle. This method of enhancing ego cognition provides a high degree of intuitive learning that connects theory with

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experience. Users can visualize the scale, anatomy, and orientation of each design element with enhanced scenario-based learning to support comprehension and confident decision-making in the design process. Reality Capture provides realistic insight into how the water treatment process connects each part of the whole-water treatment process to the content area, even for those users who do not have access to water treatment facilities.

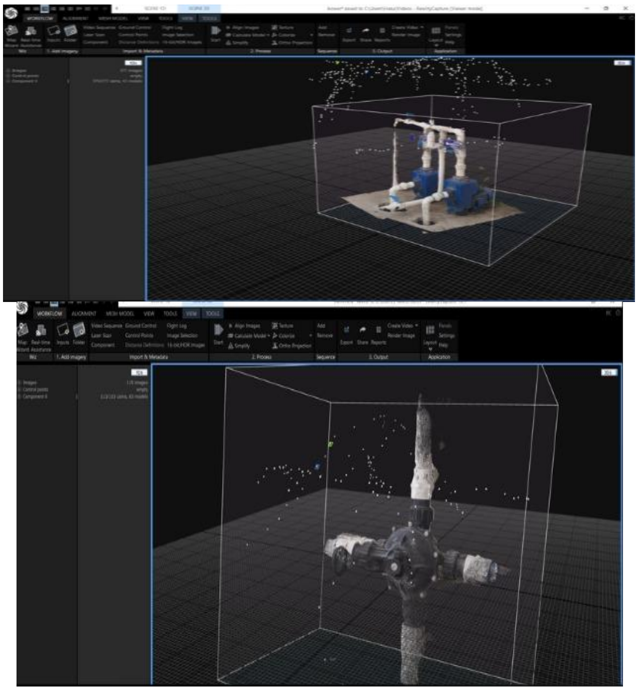

Figure 11 **Reality Capture of Machineries**

7.3. Performance

The analysis of statistics on the digital water treatment process designer indicates improvements in key performance indicators. Revenue growth is 41.67%, which means the system is yielding higher returns than previously seen. At the same time, return on investment (ROI) has reached an impressive 275%, showing the relative cost-effectiveness and efficiency of the digital solutions implemented. An additional positive indicator is a reduction in customer acquisition cost, which decreased by 43.75%. The result demonstrates the system's ability to reach and serve more customers at a lower expense. Overall, the trend seen on the graphs strongly demonstrates how having digital design and optimization in place achieves sustainable financial and operational benefit for water treatment processes.

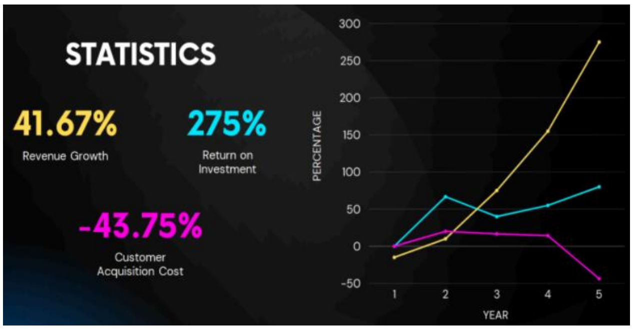

Figure 12 **Statistic Graph**

8. Result

As a result, a sophisticated web application will be developed, which is customized to optimize the parameters of the waste water which has been tested in the laboratory. This application comprehensively analyzes the parameters and set forth the required chemicals for the treatment as well as the necessary treatment equipment along with their capacities and it also generates an accurate process flow diagram of the machinery in sequence. Moreover, it calculates the total capital expenditure required for the treatment plant setup. It ensures the complete and effective solution which reduces the minor mistakes causing major problems, shown in Figure 12 [15].

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