# Optimization of RO’s Waste Water Reuse System and Water Management using Hybrid PSO-GWO

A Dissertation submitted in fulfillment of the requirements for the Degree

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*in*

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*Submitted by*


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# CERTIFICATE

I hereby certify that the work which is presented in "**Optimization of RO's Waste Water Reuse System and Water Management using Hybrid PSO-GWO**" in partial fulfillment for the award of Degree of Master of Engineering in Department of Power Systems in Electrical and Instrumentation Engineering Department of Thapar Institute of Engineering & Technology, Patiala, is an authentic record of my own work carried out under the supervision of Mr. Nitin Moudgil (Team Leader, R&D, Water purifier & Microwave, LGEIL), and Dr. Manoj Badoni (Associate Professor, EIED) and refers other researcher's work which are duly listed in the reference section.

The matter presented in this thesis has not been submitted for the award of any other degree of this or any other university.

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This is to certify that the above statement by the candidate is corrected and true of the best of my knowledge.

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**Kanchan Kumari**

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# LIST OF ABBREVIATION

| **Acronym** | **Abbreviation** |
|---|---|
| APLC | Advance Programmable Logic Controller |
| BESS | Battery Energy Storage System |
| GWEC | Global Wind Energy Council |
| GWO | Gray Wolf Optimisation |
| HRES | Hybrid Renewable Energy Systems |
| IPSO | Improved Particle Swarm Optimization |
| LVRT | Low Voltage Ride Through |
| MNRE | Ministry of New and Renewable Energy |
| MPPT | Maximum Power Point Tracking |
| NIWE | National Institute of Wind Energy |
| PHS | Pumped Hydro Storage |
| PQ | Power Quality |
| PSO | Particle Swarm Optimization |
| PV | Photo Voltic |
| RO | Reverse Osmosys |

# ABSTRACT

Wastewater treatment plays a critical role in maintaining environmental sustainability and public health. This abstract presents a proposed wastewater treatment system that utilizes advanced technologies and innovative approaches to efficiently and effectively treat wastewater. The system employs a combination of physical, chemical, and biological processes to remove contaminants and pollutants from wastewater, aiming to achieve high-quality effluent that can be safely discharged or reused.

The proposed wastewater treatment system incorporates multiple stages, including preliminary treatment, primary treatment, secondary treatment, and tertiary treatment. Each stage utilizes specific techniques such as screening, sedimentation, activated sludge process, biological nutrient removal, and advanced filtration methods. The system also incorporates advanced oxidation processes and disinfection methods to ensure the removal of residual contaminants and pathogens.

To evaluate the system's performance, comprehensive monitoring and analysis are conducted to measure key parameters such as biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), nutrient levels, and microbial indicators. Simulation models are employed to predict the system's efficiency and optimize process parameters for enhanced treatment performance.

The proposed wastewater treatment system aims to achieve several objectives, including the removal of organic and inorganic pollutants, nutrient recovery, and water reuse. By implementing advanced treatment technologies, the system promotes sustainability by reducing the environmental impact of wastewater discharge and conserving freshwater resources. The treated wastewater can be safely discharged into receiving water bodies or utilized for irrigation, industrial processes, or other non-potable applications.

# CHAPTER 1

# INTRODUCTION

## 1.1 Introduction to Company

LG ELECTRONICS is a global company based in South Korea. LG Electronics is the chief store of LG Group and it is the largest conglomerates in South Korea, one of South Korea's most powerful in Televisions, mobile phones, and home appliances are designed and manufactured by the company's 75 subsidiaries throughout the world.

## 1.2 LG –The History

Lucky Gold Star, a modest cosmetics manufacturer, was the beginning of the globally renowned corporation LG. In 1958, LG launched its Gold Star brand into the electrical industry. LG produced Korea's first telephone in the same year, refrigerator, black-and-white television. It diversified into oil refining, construction biotechnology, semiconductors, and banking throughout the years. In 1995, the company's two most known brands, Lucky and Gold Star, re renamed and given a new corporate identity. LG was formed by merging two Korean firms, Lucky and Goldstar, resulting in the acronym LG. The current tagline "LIFE IS GOOD" is an acronym. Before the company's name change to LG, home items re marketed under the Lucky brand. At the same time, electrical goods re offered under the Goldstar brand. Goldstar was rebranded LG ELECTRONICS in 1995, and the company purchased Zenith Electronics of the United States.

## 1.3 LG Philosophy

To generate value for consumers via management based on human dignity,' says the management philosophy. LG's goal is to deliver a smile to every household on the planet. LG's logo is consistent with its mission. The happy face logo represents five main ideas: World, th, Humanity, and Technology. LG thinks that combining these components will allow the company to achieve a brighter future.

## 1.4 Jeong-Do Management – LG Way

LG Electronics' 'Jeong-Do Management' (management by principle) includes strong ethical standards and open and honest business practices. LG's unique application of ethics is called "Jeong-Do Management." LG achieves success by employing ethical management methods and continuously improving business abilities. At the core of LG Way lies the management's dedication to creating value for customers and upholding human dignity. Management by Principle not only prioritizes open and fair competition but also emphasizes fostering essential skills among LG employees. These skills are crucial in delivering significant value to consumers and earning their trust.

**1.5 Some Facts at Glance About The LG**

- LG is a multibillion-dollar corporation with a market capitalization of $80 billion dollars.
- It's the country's third-largest corporation. LG is a firm that considers its employees to be its most valuable asset.
- According to a poll conducted by Business Today, it is India's sixth-best employer.
- LG considers itself to be a global corporation with a champion mentality, with a presence in over 175 countries across the world.

**1.6 Product Portfolio – LG Home Appliances**

**LG Refrigerator:** LG Refrigerator has Nano carbon deodorizing automation that has earned LG the “KT new technology mark.” LG has introduced a comprehensive line of frost-free diamond-cut freezers with capacities ranging from 230 to 731 liters. Products manufactured by LG Electronics (Home appliances). The firm presently offers six 230 L versions, four 250 L variants, and five 310 L varieties. The business also released two 350 and 390 liter versions, as ll as six 400+ variants.

**LG Air Conditioners:** LG ELECTRONICS is credited for significant growth in the global use of air conditioners. On the design aspect, the new AC line is outstanding. The new flat panel splits are based on worldwide air conditioning trends and the demand for consumers to improve their indoor aesthetics. LG has unveiled the INTELLOEYE technology, which was created in-house and is based on sophisticated sensors. When the INTELLOEYE mode is on, the AC's inbuilt intelligent sensor senses the room temperature. It changes the temperature, fan speed, and swing settings accordingly. Introduced the dual-display option in splits to provide convenience to clients, allowing them to see both the room and the preset temperature shown on the AC. LG air conditioners with Inverter V technology now have split AC with variable tonnage, which provides 1.7 times quicker cooling and up to 66 percent energy savings.

**LG Microwave Oven:** LG has released the solar Dom and waves DOM microwave ovens, which are high-end microwave ovens. With its unique light wave technology, the LG solar DOM is presently the world's best microwave oven. It enables three times quicker cooking, excellent nutrition retention. .

**LG Washing Machines:** LG Electronics launched TROMM line of drum cleaning machines. symbolic logic technology ensures that as click the beginning button, clever transmitters immediately identify the laundry load and water level—machines with a turbo drum and a three-step wash cycle that provide the fore most excellent results.

**LG Water Purifier:** LG's water purifier offers a two-in-one solution that includes a UF filter system for further convenience. On the side of the water, purifiers are vegetable and fruit cleaners. It is designed to clean veggies and fruits while also conserving water. It aids in maintaining the product's high efficiency and performance for an extended time. As a result, may enjoy clean and nutritious water for a longer time.

**LG Audio and Home Theatre:** LG currently has a complete line-up of 17 items to offer its customers, making it one of the most comprehensive audio product lines available. LG's audio lineup includes the most advanced wireless mp4 home theatres, mp3 home theatre systems, and a Room theatre system.

**LG LED TV:** LG has worked with nearly every 3D flavor imaginable in the television business. This 3D-capable 47-inch TV looks amazing and comes with a solid range of features. In the living room, the 3D LED TV is extremely attractive. It has many features, and there are moments when the 3D LED.

### 1.7 Core Competencies

LG believes its core competencies as:

- **Design:** The ability to properly plan projects and businesses in order to get the best possible results.
- **Technology:** The capacity to develop and sell innovative product concepts using new proprietary technologies ahead of the competition.
- **Marketing:** The ability to properly comprehend and evaluate consumer demands before linking them to business and maintaining brand image control.

### 1.8 Services Offered

LG Electronics Repair Service: If LG Consumer Electronics device has reached the end of its warranty period, LG recommends contacting 'Domestic and General,' who can provide extended warranty services at a reasonable cost. LG Electronics has been focusing resources and capabilities in the field of R&D from the beginning to build a digital world that enriches people and become a Global Top Leader of the digital era in the twenty-first century. LG Electronics' R&D goal aims to create new standards in emerging sectors by creating technologies that connect the Internet and networks while continuing to deliver world-class goods. LG Electronics has developed active cooperation relationships with research groups in and outside of Korea to foster a culture on R&D in the digital sector. In 2001, LG began household manufacturing of its refrigerators and set up a response line for PC monitors at its Greater Noida manufacturing unit, in an area of more than 50 acres, the company started making color televisions, air conditioners, refrigerators, washing machines, microwave ovens. Similarly, a microwave has a "Health Wave System", a refrigerator has a "PN System", which stores vitamins in meals, and a washing machine has a "Fabricate System", which takes matter of body condition down to clothes. The business enterprise had until the month of October2001 carried out a cumulative turnover of Rs 5000 Crores in India considering the fact that its origin in 1997, making it the quickest ever Rs. 5000 Crores clocked with the aid of using any business enterprise within side the Indian purchaser electronics and domestic home equipment industry. LGEIL is proud to have Stud of allowed approximately 24 villages across the Greater Noida facility.

### 1.9 Water Purifier

Water purification approach the system of disposing of unwanted chemicals, organic contaminants, suspended solids, and gases from water. The purpose is to provide water this is match for unique purposes. Primarily, water is purified and disinfected to make it suitable for human consumption. However, water purification serves a multitude of other purposes, including medical, pharmacological, chemical, and industrial applications. The history of water purification encompasses a wide range of techniques. The techniques used consist of bodily procedures including filtration, sedimentation, and distillation; organic procedures including gradual sand filters or biologically lively carbon; chemical procedures including flocculation and chlorination; and the usage of electromagnetic radiation including ultraviolet light. The requirements for consuming water highsatisfactory are usually set via way of means of governments or via way of means of worldwide requirements. These requirements commonly consist of minimal and most concentrations of contaminants, relying at the meant use of the water.

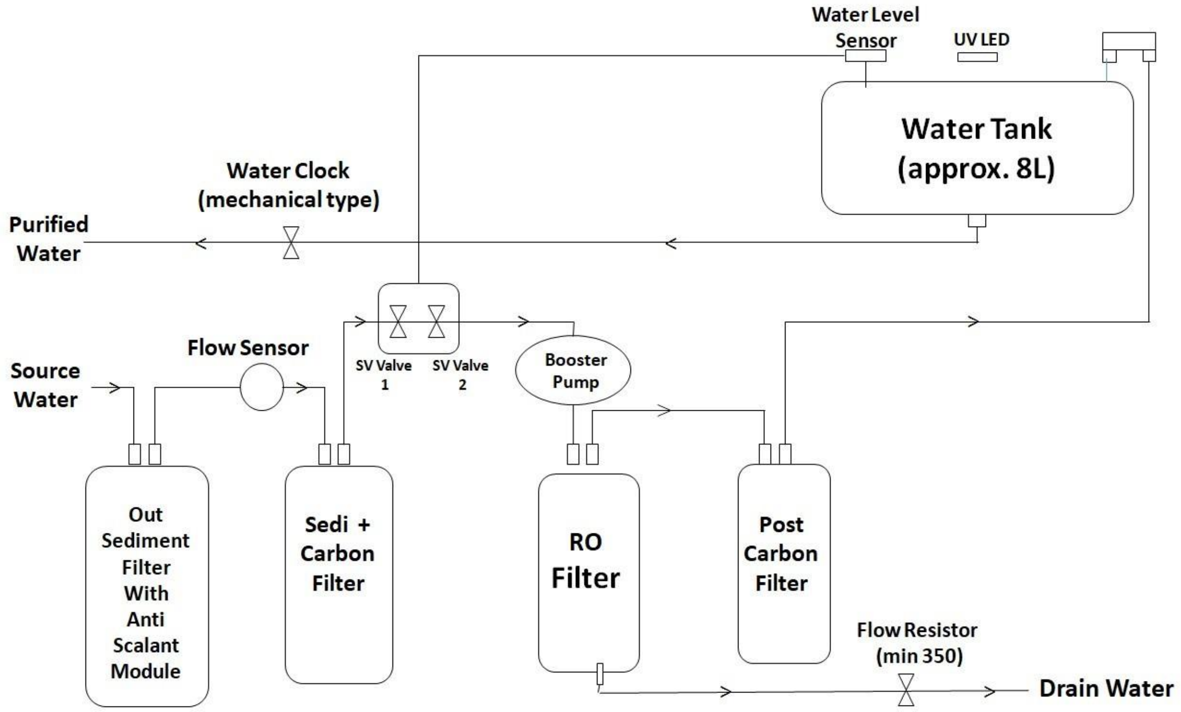


**Figure 1.1: LG Water Purifier Block Diagram**

## 1.10 Working Principle of Water Purifier

- Source water is coming inside the out-sediment filter. The dregs and particles in the water get separated from the flow.
- Then water passes through the flow sensor to the sediment + carbon filter.
- Then the filtered water passing through the solenoid valve and then the out let of the solenoid valve is connected to the RO membrane.
- The Ro membrane has mainly one inlet and two outlets.
- The First outlet is the RO filtered water and the Flow restrictor is connected to another outlet of RO membrane so that maximum water can pass through the RO membrane.
- The RO filtered water is passing through the Mineral booster filter to enhance the taste of the water.
- Then the water is directly transferred to the water purifier tank.
- Solenoid Valve: To turn off the flow when the flow sensor does not detect any flow and when water level sensor indicates that the tank is full.

- Main Pcb: To control all the electrical and electronic parts.
- Flow Restrictor: To build pressure inside the RO membrane so that maximum water can be purified through the RO membrane.

## 1.11 Field Failure Analysis

Failure Analysis is the procedure of amassing and reading statistics to decide motive of failure, regularly with the purpose of figuring out corrective movements or liability. The Field failure contribution parts are:

- Booster pump
- Flow sensor
- Level sensor
- Flow

**Overview**

In places where there isn't enough water, every drop needs to be treated with care because water has an unknown value. People are coming to the realization that water issues are one of the most evident and serious environmental hazards to people. This awareness is growing all the time. Since 1950, the amount of water that has been utilized everywhere in the globe has increased by a factor of three. Despite this, one out of every six individuals do not have consistent access to clean, drinking water that has not been contaminated. Every year, about 1.2 billion people's health is hurt because they don't have access to clean water or good toilets [1].

## 1.12 Wastewater Reuse

The word "wastewater" is used to describe any water that is no longer needed because it can't be used to make anything else better. Les solid wastes make up less than one percent of garbage. The other 99 percent is water. Reusing water means bringing back water that has been cleaned and used for something else. Because the user doesn't get this water from a natural source like a river or the ground, [2] call it a "reuse." This is because the water is a result of how people clean up after themselves and how factories work. When waste components are taken out of treated wastewater to an accepted level, it can be used in a variety of ways that are good for agriculture, businesses, homes, and industries without the risk of contamination.

The value of wastewater is slowly being recognized in arid and semi-arid areas, and many countries are looking forward to improving and increasing the ways they can reuse wastewater. In recent years, effluent reuse has become an important part of managing water resources for both environmental and business reasons. Researchers and scientists are looking at it as one way to meet the water needs of future generations. They are aware of both the benefits and the risks.

Reusing effluent has been done for a long time, and farm irrigation is the biggest user of reclaimed effluent by volume. It is expected that this trend will continue to growin particular in countries that are still developing. Another important consumer group is the industrial sector, particularly for the processing and chilling of goods. The second kind of reuse that can be done is called indirect reuse. Rainwater that has been recovered to a high degree can be reintroduced into the groundwater system to restore depleted aquifers. According to Metcalf and Eddy (2003), this kind of water reuse is considered indirect because the water that has been reclaimed will be combined with the groundwater.

In Palestine, projects that involve reusing wastewater are affected by politics, money, culture, institutions, and technology, among other things. Israel thinks that reused wastewater is part of the Palestinians' general freshwater quota (Samhan, 2008). This means that the problem of reused wastewater is still tied to the political problems over Palestinian water rights.

### 1.13 Wastewater Characteristics

Wastewater characteristics can vary depending on the source and type of wastewater. However, there are some common characteristics that can be found in wastewater:

**Physical Characteristics:**

**Color:** Wastewater can range from clear to various shades of gray, brown, or even black, depending on its composition.

**Temperature:** Wastewater temperature can vary depending on its source, such as industrial processes or residential discharge. It can range from cold to warm or even hot.

**Turbidity:** Turbidity refers to the cloudiness or haziness of wastewater caused by suspended solids, such as particles, colloids, or organic matter.

**Chemical Characteristics:**

pH: The pH level of wastewater indicates its acidity or alkalinity. It can range from acidic (pH $< 7$) to alkaline (pH $> 7$). The pH of wastewater can affect the performance of treatment processes.

**Chemical Oxygen Demand (COD):** COD determines the quantity of oxygen that must be present in wastewater for the oxidation of organic and inorganic materials. It offers an assessment of the organic content as well as the pollution level of wastewater.

**Biochemical Oxygen Demand (BOD):** BOD determines the quantity of oxygen that is used by microorganisms in the process of degrading organic matter that is found in wastewater. It is a measurement of the amount of organic material in the water that is capable of biodegradation.

**Dissolved Solids:** Wastewater can contain dissolved substances such as salts, minerals, heavy metals, nutrients (nitrogen and phosphorus), and organic compounds.

**Biological Characteristics:**

**Pathogens:** Wastewater may contain various disease-causing microorganisms such as bacteria, viruses, and parasites. These pathogens pose a risk to human health and the environment if not adequately treated.

**Biological Diversity:** Wastewater can support a diverse microbial community, including bacteria, fungi, algae, and protozoa. These microorganisms play a role in the degradation and transformation of organic matter.

**Suspended Solids:**

Total Suspended Solids (TSS): TSS refers to the total mass of particles that are suspended in wastewater. It includes both organic and inorganic solids.

**Settleable Solids**: Settleable solids are the particles in wastewater that settle to the bottom of a container under quiescent conditions. They are measured using the Imhoff cone or similar methods [3].

## 1.14 Types of BOD

The physical, biological, and chemical properties of the liquid as it moves out of a component make up the quality of the cleaned wastewater. The following things can also be added to the list of things that are trash:

**I- Biochemical Oxygen Demand**

The term "biochemical oxygen demand" (BOD) refers to the amount of dissolved oxygen that microorganisms use in the course of the process of microbiological and chemical oxidation of the contents present in a wastewater sample over the course of an incubation period at a particular temperature. This takes place over the course of a certain amount of time. The amount of oxygen that is used up during the simultaneous oxidation of carbon and nitrogenous substances is known as the biological oxygen requirement.

**II- Biochemical Oxygen Demand (BOD5)**

The Biochemical Oxygen Demand-5days is the amount of dissolved oxygen that was consumed by microorganisms during the breakdown of organic matter in a wastewater sample over the course of five days of incubation at a temperature of 20 degrees Celsius. This value is expressed in mg/L. It is a method that is used to demonstrate the quantity of organic matter that is present in the sample.

**III- Chemical Oxygen Demand (COD)**

The quantity of organic matter that is oxidised by a powerful chemical oxidant is what is meant to be measured by the term "chemical oxygen demand." In situations in which the BOD5 test would be invalid, the chemical oxygen demand (COD) test is carried out to determine the amount of organic matter present in effluent from commercial and industrial facilities as well as municipal water treatment plants. In most cases, the COD test may be completed in less than one hundred fifty minutes, and the COD levels are invariably higher than the BOD5 levels for the same wastewater sample. When the COD/BOD5 relationship for a particular facility is known, and the COD content of an effluent can be calculated, it is normally easy to estimate the BOD5 concentration of the effluent. The vast majority of circumstances adhere to this pattern [4].

## 1.15 Treatment Methods

The term "operations" refers to the various types of land reclamation techniques that emphasize the application of physical forces. Processes are a type of pollution control method that reduces the amount of pollutants in an environment via the use of chemical or biological reactions. In modern times, several procedures and processes are combined in order to provide multiple levels of treatment. The following levels of treatment are included in this category: preliminary, primary, advanced primary, secondary, tertiary, and advanced (Quandary) treatment. In order to protect the machinery from wear and tear during the preliminary treatment phase, it is imperative that all particles, including big debris, sand, and grit, be eliminated from the substance. Sedimentation is a physical process that is used in the first stage of the wastewater treatment process, which is known as primary treatment. This process is used to remove the components of the wastewater that are able to float and settle out. It is possible to achieve the objective of improved removal of suspended and dissolved particles with the addition of chemicals, which is a realistic approach. During the second stage of treatment, biological and chemical processes are combined in order to get rid of the vast majority of the organic components. In the tertiary treatment, extra operations and processes are used to remove any remaining suspended particles and other components that were not eliminated by the normal secondary treatment that came before it. This treatment comes after the typical secondary treatment. This is done in order to bring the water quality back up to acceptable levels. Membrane technologies like as UF/RO, which are used in Quaternary (Advanced) treatment, are able to create drinkable water quality while simultaneously removing all of the different types of pollutants that are left over from tertiary treatment [5].

In order to be able to reuse effluent, it is necessary to treat it in such a way that it satisfies certain quality standards that are tailored to the particular requirements and ensures the public's safety. The following are the three types of wastewater reclamation techniques that can be categorized:

**Physical process**: Include procedures that treat wastewater without significant chemical or biological alterations and instead rely on physical phenomena, such as coarse screening to remove larger particles, sedimentation to allow solids to settle out by gravity while allowing liquids to flow and be skimmed, adsorption to use activated carbon to remove organics, and ion exchange to exchange certain ions.

**Chemical process:** The process of neutralization, which involves the addition of acid or base to change pH levels in order to achieve neutrality, is one of the many chemical processes that are utilised in effluent reclamation operations. Other chemical processes include: The process of coagulation, which involves the addition of a chemical in the course of a chemical reaction, results in the formation of a component that cannot be solved and that is thus straightforward to remove from wastewater.

**Biological process:**When bacteria or other organisms are used to stabilise the components of wastewater during its biochemical degradation. More microbes, or sludges, develop, and some of the pollutants are converted to carbon dioxide, water, and other substances. According to the availability of dissolved oxygen, biological treatment processes can be broadly classified into two groups: aerobic and anaerobic.

The objective of wastewater treatment is typically to remove enough contaminants and solids from the wastewater, both organic and inorganic, so that the treated wastewater is suitable for non-portable purposes or even for discharge in ecosystems, and the solids that are removed can be recovered as sludge. Sludge is a byproduct of the wastewater treatment process. A final treatment can be necessary to eliminate smells, sluggish biological activity, and kill pathogenic organisms [6].

### 1.16 Quaternary (Advanced) Treatment Using Membrane Processes

When the wastewater is going to be reused for a variety of uses, or when it is going to be discharged into ecosystem, The degree of treatment that will be provided to municipal effluent will probably be in accordance with the necessary requirements for recovered wastewater that have been set by either local or international regulatory organisations. The tertiary-treated effluent is next subjected to quaternary treatment at a number of treatment facilities, which involves the utilization of membrane technologies. This results in an effluent that is suitable for use in any form of water reuse application.

To separate dissolved and suspended materials from water, membrane technology makes use of a membrane that is only partially permeable. It has been used for a significant number of years in the desalination of brackish and saltwater, and only lately has it been implemented in the field of wastewater treatment.

More and more people are paying attention to membrane technologies including microfiltration, ultrafiltration, nanofiltration, and RO, which are gaining specific prominence as alternatives to traditional methods of treating wastewater and expanding the applications for reuse of treated wastewater.

Reverse osmosis, also referred to as RO, is a wastewater treatment method that has seen a major rise in popularity in recent years. Around the world, there are now a sizable number of large-scale municipal wastewater treatment facilities that are either in service or being built. The main driving force behind this choice is the relatively low amount of energy that RO uses in compared to other technologies. High levels of contaminants and pollutants removal are another factor. The most important aspect of the design of a RO wastewater treatment system is the adoption of an appropriate pretreatment technique, such as ultrafiltration (UF) or conventional pretreatment, to remove suspended solids in order to reduce membrane fouling and lengthen membrane life. As an acceptable pretreatment method, ultrafiltration (UF) is one example [7].

## 1.17 Potential of Wastewater

Applications That Can Be Reused The application of recycled wastewater is contingent on a numberof factors, including availability, Demand, treatment needs, and distribution and storage infrastructure. Additionally, concerns about ecological and health risks are typically linked to the reuse of wastewater. As a result, acceptance of the accompanying health risks and environmental consequences is crucial for the adoption of alternate water sources as a replacement for irrigation. The following is a list of the most common types of recycling and reuse:

### Agricultural Use

Weather directly affects how much treated wastewater is needed for irrigation, which changes from month to month throughout the year. Seasonal variations in temperature, rainfall, and other factors including the type of crop, the stage of growth a plant is in, and the irrigation system are also factors.

The provider of treated effluent ought to take into mind these seasonal requirements and the variation in the quality of the influent in order to fulfil the requirements that are placed on agriculture. In order to determine whether or not it is feasible to reuse treated wastewater, the provider of such wastewater must be able to conduct an objective analysis of the demands placed on agriculture and the inputs available.

The main issues with using treated wastewater in agriculture include salinity, salt, trace elements, excessive chlorine residuals, and high chlorine levels. A plant's level of sensitivity is mostly determined by its personal tolerance to a substance that is either deposited on the soil or located in the root zone. The likelihood of treated wastewater having higher concentrations of these elements than untreated water sources is higher. The water supply, the wastewater flow's nature (domestic or industrial), the amount and nature of infiltration in the sewage system, the effluent reclamation procedures, and the kinds of storage buildings all affect the types of components and concentrations of those components in treated effluent. The treated wastewater from municipal sources is of a sufficient quality for use in emergency situations.

**Groundwater Recharge**

Recharging the groundwater is one of the best ways to reuse reclaimed wastewater. This is because the earth can filter water and break down organic matter. This gives the effluent that is already there more treatment and makes it more likely that the treatment will work for the whole effluent control system.

Depending on the method used for recharging, the hydrogeological conditions, the needs of the user, and other factors, The requirement for sophisticated wastewater treatment plants may be eliminated by the treatment that can be carried out in the subterranean environment. In other instances, the groundwater and treated wastewater have mixed together to such an extent that they cannot be separated. Recharging groundwater keeps cleaned wastewater from mixing with groundwater, which can cause the water to lose its name. So, this could increase the number of ways that recycled wastewater can be used and make it easier for people to accept that things can be reused. In general, some of the following goals can be met by using reclaimed water to fill up groundwater:

- Take measures to prevent saltwater from seeping into coastal aquifers.
- Offer cutting-edge treatment for potential reuse in the future.
- Refill the groundwater aquifer for use in both potable and non-potable applications.
- Allows for the storage of water that has been recycled.

Despite the fact that groundwater recharge has a number of observable benefits, there are also potential drawbacks that should be taken into account (Oaksford, 1985):

- Being able to cover enormous land areas while still doing operations and maintenance
- The cost of the energy needed to recharge wells could be high.
- The likelihood of polluting an aquifer may increase if recharge is performed.
- Could potentially result in liability and other legal issues.
- The slow circulation of groundwater is unable to keep up with the unexpected surge in demand.

**Industrial Reuse**

The reuse of reclaimed water in industrial settings is a significant and potentially lucrative business on a global scale. Many different types of manufacturing are ideal candidates for the use of reclaimed water since their operations do not require the purity of drinking water. In-plant recycling of industrial wastewaters or municipal water reclamation plants are two possible sources for treated wastewater intended for reuse in industrial settings. The practise of recycling inside an industrial plant is typically an essential component of the manufacturing process and needs to be developed on an individual basis. Reclaiming and reusing an industry's effluent is necessary for the preservation of water as well as for meeting or avoiding stringent regulatory rules for wastewater disposal.

However, the use of recycled, high-quality treated effluent for agricultural irrigation is crucial not only to protect public health but also to take into account a best preservation plan to reduce the consumption of constrained potable water for agriculture and to minimize fertilizer costs in the agricultural strip of low-income territories (Zurita& White, 2014). This is due to the fact that using reclaimed sewage for agricultural irrigation safeguards the public's health, which is crucial. According to AHT GROUP AG, 2009, there are three key obstacles to overcome when reusing wastewater for irrigation in agriculture.

**1. Quality requirements**: in order to reduce the severity of any and all adverse impacts on human health and the environment. In order to accomplish this goal, water that is going to be reused would need to undergo the appropriate treatment, and safe irrigation practises would need to be put into place.

**2. Seasonal demand**: Since irrigation is only required during certain times of the year, proper storage facilities would need to be constructed in order to accommodate the constant production of wastewater.

**3. Location of production**: Large cities are responsible for the generation of the biggest quantity of wastewater, whereas agricultural regions are often situated in more remote rural districts. Asa consequence of this, infrastructure for pumping and long-distance transportation networks would be required [8,9].

### 1.18 WHO Guidelines for Waste Water Reuse

The World Health Organisation (WHO) has created recommendations for the secure reuse of recycled wastewater in agricultural irrigation. By following these recommendations, we can make sure that farmers, employees, and customers won't face any major health hazards as a result of the usage of reclaimed effluent in irrigation practises. WHO recommendations for recovered wastewater reuse in agricultural irrigation have the following key features:

**Multiple Barriers Approach:** The guidelines promote a multi-barrier approach to safeguard public health. This approach involves implementing a combination of risk management measures at different stages of the water treatment and irrigation process to minimize potential health hazards.

**Health-Based Targets**: The guidelines establish health-based targets for specific contaminants, focusing on the protection of public health. The targets set limits on the concentration of microbial indicators, chemicals, and other potential hazards in the reclaimed effluent used for irrigation.

**Risk Assessment:** The guidelines emphasize the importance of conducting a thorough risk assessment specific to the local context. This assessment considers factors such as the characteristics of the wastewater, irrigation practices, crop types, exposure pathways, and the vulnerability of the population to potential health risks.

**Wastewater Treatment Requirements:** The guidelines provide recommendations for wastewater treatment processes to ensure the removal or reduction of pathogens, suspended solids, organic matter, and specific chemicals. The effectiveness of treatment should be verified through monitoring and testing.

**Irrigation Practices and Management:** The guidelines outline good agricultural practices to minimize potential exposure to contaminants during irrigation. This includes appropriate irrigation techniques, water distribution methods, and timing of irrigation to reduce direct contact with crops and workers.

**Monitoring and Surveillance:** The guidelines emphasize the importance of regular monitoring and surveillance programs to assess the quality of the reclaimed effluent, the irrigation system, and the crops. Monitoring helps to detect any changes or deviations from the established standards and enables prompt corrective actions.

**Institutional Framework:** The guidelines highlight the need for a strong institutional framework and regulatory oversight to ensure compliance with the guidelines. This involves clear roles and responsibilities for various stakeholders, including water and agriculture authorities, health agencies, and farmers [10].

**Indian Standards**

In India, the guidelines for water reuse are primarily provided by the Central Pollution Control Board (CPCB) and the Bureau of Indian Standards (BIS). These guidelines establish the standards and procedures for water reuse in various sectors. Here are some key guidelines related to water reuse in India:

**CPCB Guidelines for Water Reuse**: The CPCB has published guidelines titled "Guidelines for Water Reuse" that provide a framework for the safe and sustainable reuse of water. These guidelines cover different aspects, including the treatment requirements, quality parameters, and recommended uses of reused water.

**BIS Standards:** The Bureau of Indian Standards has developed standards related to water quality, treatment, and reuse. The relevant standards include:

**IS 10500:2012 -** Drinking Water Specification: This standard sets the permissible limits for various physical, chemical, and microbiological parameters in drinking water.

**IS 3025:2009 -** Methods of Sampling and Test (Physical and Chemical) for Water and **Wastewater:** This standard provides guidelines for sampling and testing of water and wastewater to assess their quality.

**IS 2296:1982 -** Methods of Test for Water and Wastewater (Microbiological): This standard specifies methods for microbiological testing of water and wastewater.

**IS 13593:1992** - Recycled Water for Industrial Uses - Specification: This standard provides specifications for the use of recycled water in industrial applications [12].

### 1.19 Motivation

The motivation behind water reuse stems from several key factors and objectives. Here are some common motivations for implementing water reuse practices:

**Water Scarcity Mitigation:** Water reuse is motivated by the need to address water scarcity challenges. By reusing treated wastewater or reclaimed water, it helps reduce the demand for freshwater resources, particularly in water-stressed regions. Water reuse offers an alternative and sustainable water supply, ensuring the availability of water for various sectors, including agriculture, industry, and municipal uses.

**Sustainable Water Management:** Water reuse aligns with the principles of sustainable water management. By utilizing reclaimed water, it reduces the reliance on freshwater sources and minimizes the environmental impact of water extraction. Water reuse contributes to the conservation and preservation of freshwater ecosystems, protecting natural habitats and maintaining ecological balance.

**Diversification of Water Sources:** Water reuse provides an additional source of water, diversifying the water supply portfolio. It offers resilience against droughts, climate variability, and other water supply disruptions. By integrating water reuse into water management strategies, communities and industries can reduce vulnerability to water shortages and ensure a reliable water supply.

**Environmental Protection**: Reusing treated wastewater helps protect water bodies, as it reduces the discharge of effluents into rivers, lakes, and oceans. By treating and reusing wastewater, it minimizes pollution and the potential negative impacts on aquatic ecosystems, wildlife, and human health. Water reuse promotes the conservation of water resources and supports sustainable development practices.

**Economic Benefits:** Water reuse can bring economic benefits to communities and industries. It provides a cost-effective alternative to freshwater sources, reducing the costs associated with water acquisition, treatment, and distribution. Additionally, water reuse supports agricultural productivity, industrial operations, and urban development, contributing to economic growth and job creation.

**Energy Efficiency and Resource Recovery:** The motivation behind water reuse also lies in the potential for energy savings and resource recovery. Wastewater treatment and reuse technologies can be designed to optimize energy efficiency and promote the recovery of valuable resources, such as nutrients and organic matter. These recovered resources can be utilized for agricultural fertilization or energy generation, promoting a circular economy approach.

**Climate Change Adaptation**: Water reuse plays a crucial role in climate change adaptation. As climate change impacts water availability and exacerbates water scarcity, reusing water becomes essential for adapting to changing climatic conditions. Water reuse strategies contribute to climate resilience by conserving water resources, reducing energy consumption, and mitigating greenhouse gas emissions associated with freshwater extraction and treatment.

These motivations collectively drive the adoption of water reuse practices, supporting sustainable water management, environmental protection, and resilience in the face of water scarcity and climate challenges.

### 1.20 Objectives

The aim of water reuse is to create a sustainable and reliable water supply by utilizing treated wastewater or reclaimed water as a valuable resource for various sectors, while ensuring the protection of public health and the environment. The aim of the study is to optimize the selection of water between RO water and fresh water by employing a search optimization algorithm. The purpose of this study is to evaluate the possibility for sustainable management practises for treated wastewater and the necessity for such practises. The following are the goals.

1. Review the rationale and justification for reusing treated wastewater;
2. Understand the impacts of current treated wastewater management actions on ecosystem, human and animal health, and their economic consequences;
3. To design and develop a search optimization algorithm that can evaluate the choice between using RO water and fresh water based on specific criteria and constraints.

4. To define an objective function that considers various factors influencing the water selection decision.

5. To evaluate the performance of the algorithm in selecting the optimal water source.

6. To determining the amount of water reused, power consumption associated with RO water treatment, and the amount of fresh water saved by utilizing RO water.

# CHAPTER 2

# REVIEW OF LITERATURE

## 2.1 Introduction

The validity of an adaptation measure and its ease of implementation are both affected by the degree to which it enjoys social and political acceptance. The community's social, economic, and environmental aims and objectives should all be taken into account when formulating a response to the reuse of treated wastewater.

The viability of selling cleaned wastewater to food producers is one definition of "market feasibility," while the commercial viability of items grown in wastewater is another. Certified organic product sales at conventional grocery stores were analysed in a 2006 study supervised by the Organic Agriculture Centre of Canada (OACC). Statistics Canada (2009) revealed that between 2005 and 2006, sales of certified organic food increased by 28% overall, with a 31% increase in sales of prepackaged goods and a 22% increase in sales of fresh products. However, in neither Canada nor Ontario has research been conducted on how farmers view the use of treated wastewater. Nonetheless, Forge (2004) reports that only 1.3% of Canadian farmers are engaged in organic production on slightly more than 390,000 hectares.

Most farmers who have expressed interest in organic farming have cited environmental concerns and a desire to avoid exposure to agricultural chemicals as motivation. Energy consumption is also a problem in agriculture because so many agricultural chemicals are produced through high-intensity procedures that use plenty of fossil fuels. When compared to conventional farming, organic farming is more lucrative and satisfying for farmers [13].

## 2.2 Literature Review

**R. Seetharaman et.al.** (2022) Water is a unique and widely available natural resource. Seventy percent or more of Earth's crust is covered by water. Only 27% of the water in the Earth's crust is drinkable due to impurities; the remaining 97% is saline. Icebergs and glaciers account for the remaining 3%. The value of water has grown enormously alongside the development of industry and technology. Water reusability was a topic of discussion at the time among environmental campaigners. The term "reusability" refers to the practise of recycling wastewater from commercial or residential applications. "Desalination" refers to one of the most popular water reuse processes. Saltwater desalination is the method used to reduce the amount of salt in a body of water. It calls for massive plants employing permeable membranes. Equally important to the desalination process is reusing the water on both industrial and home scales. Water reuse on an industrial scale involves a wide variety of techniques, but on a household size, the options are more constrained. Here, we propose a system that addresses this issue head-on by making it possible to reuse wastewater on a smaller scale, particularly at the household level, while maintaining control over the decision-making process regarding parameters like pH and turbidity [14].

**S. Tammaruckwattana et.al. (2022)**The boiler feed water used in incinerators of small and medium-sized plants in Thailand's petrochemical industrial estate is purchased from an external boiler feed water provider, and the steam condensate water produced during the incinerator process is sold back to the provider. Since the money made from peddling the water after it has been boiled is less than the money spent on purchasing it, the difference is a loss. This study proposes research into increasing the quality of steam condensate water so that it can be reused. In order to lower OPEX, it is recommended that this application be taken into account before proceeding with the construction of the steam condensate treatment unit for treating water. With the help of a plant control system and an online analyzer, water quality is monitored and treated in real time so that it can be reused [15].

**Ayush K Dudhpachare et.al. (2022)**There is a growing concern with the amount of potable water available due to the fact that the Reverse Osmosis (RO) rate uses so much water. Water disposal accounts for the remaining 25%. The remaining 75% will be put to better use elsewhere as well. In India, daily water waste amounts to over $2.43 billion. With the use of reverse osmosis and the Internet of Things, the water can be made drinkable. Here, Internet of Things (IoT) and sensor technology are used to construct a system that will collect residential RO wastewater in a central tank for later reuse on public infrastructure grass and vehicle cleaning. Every single one of our designs incorporates an ESP32. In other words, ESP32 is a clever device. The design will incorporate sensors including a soil moisture sensor, a water level indicator, and a Digital Temperature and Humidity sensor (DTH11). In order to provide users with real-time information about the health of the system, the authors of this study developed a user interface (UI) based on the blynk software. Clean Water can be conserved with the proposed design. This humble beginning will also assist Atmanirbhar Bharat in laying the groundwork for a resource-conscious society [16].

**K.Lakshmi Narayanan et.al. (2023**) Since water is so vital to human survival, it is incumbent upon everyone of us to treat it with the highest respect. The expansion of the economy, which is in turn dependent on the accessibility of water, attributes agriculture as a key contributor. Due to severe water shortages and agricultural failure, today's scenario is marked by unpredictable and uncertain rains as the monsoon rainfalls have been erratic in recent days. Several technological advancements have been implemented in agricultural settings to improve the efficiency of the irrigation system and so counteract these issues. With the help of the Internet of Things (IoT), this study implements a revolutionary AI-based system to regulate water usage in municipal wastewater treatment plants. The brains of the operation are an Atmega 328p Microcontroller linked to an ESP 8266 Wi-Fi on the chip. The water's characteristics, such as its pH, conductivity, colour, odour, and temperature, are logged in the cloud server and then analysed by an AI-based system to determine whether or not it may be reused or should be passed on to the garden for irrigation [17].

**Marini Othma et.al. (2022)**Data centres have become increasingly responsible in shouldering the responsibility of operating sustainably in light of the realisation that the energy consumption due to digital applications would continue to climb dramatically while climate change has continuously demand efficiency in the energy use. The waste heat produced by the data center's operating and cooling process should be one focus of any environmentally friendly approach for the facility. The Scandinavian countries are making significant progress, but many others have not yet followed suit. To further understand the feasibility of installing waste heat recovery for use by relevant systems in the vicinity of urban data centres in Malaysia, a case study is done. In terms of safety, security, and dependability, it has been determined that data centres have reached a positive state. From an energy efficiency standpoint, though, there is a long way to go. More research is needed to determine how to best implement waste heat recycling techniques in urban data centres in Malaysia to boost their efficiency and reduce their carbon footprint [18].

**U. Vinothkumar et.al. (2022)**Pollution occurs when potentially harmful compounds are released into the environment, including the land, water, and air. Polluted air, water, and land are all examples of environmental factors. Pollution of the natural environment is one of the most pressing issues that needs quick attention in developed countries. Inefficient waste management, including incineration and landfill disposal, is a major contributor to environmental degradation. This is why we advocated developing a system for recycling and repurposing trash as a means to cut down on environmental damage. Using the suggested strategy, Prime Minister Modi's Swaccha Bharat Abhiyan, which aims to clean up India, is also possible and may be completed efficiently. The paper proposes a novel approach, wherein different types of waste are sent to different bins based on the readings of sensors placed along the conveyor belt on which the waste, after being initially crushed, travels. Several sensors installed at strategic points along the conveyor belt can help with this. This strategy is proposed for use in the study. Glass shards, wood chips, plastic remnants, and other assorted trash are only some of the things that need to be sorted in the proposed position. The economic worth of rubbish can be maximised by recycling its dry components, such as wood, glass, and plastic, and by turning its moist components into organic manure for plant development. To achieve this goal, wet trash can be converted into organic manure. This improves the waste's chances of being useful in the economy's recycling loop. The proposed process is repeatable, and programmable logic controllers (PLCs) are the core component we're using [19].

**Yan Quet.al. (2022**)Powdered activated carbon (PAC) has been investigated as a potential adsorbent for treating water contaminated with perfluorooctanoic acid (PFOA). PFOA is readily adsorbed by PAC, demonstrating a strong affinity for its surface. In the first hour, PAC can absorb more than 95% of PFOA. The most optically viable concentration of PAC in typical reuse water was 0.125 g/L. IR spectra show that PAC is a cheap and efficient adsorbent for getting rid of PFOA in wastewater so that it can be reused. Based on the study's findings, a new method for removing PFOA from the water reuse system was developed, laying the theoretical groundwork for PFOA physical removal technology [20].

**Shuguo Zhang et.al. (2022**) In this article, we looked at how the PH value of the feed water affected the efficiency of the reverse osmosis system used to recycle water from the cooling towers of a power station. Experiments were conducted at several PH values of the feed water to determine the maximum recovery rate under the assumption that the concentrated water would not scale. Researchers looked into how the PH level in the feed water affected the desalination rate of a reverse osmosis system, and found that a PH range of 8.0–9.0 resulted in the highest desalination rate of 99.6%. Based on a cost-benefit analysis of several various operating conditions, it was determined that a PH value of 8.0 yields the highest systematic recovery rate from a reverse osmosis system, at 72% [21].

**Ravi Kishore Kodali (2022**)The growing human population poses a severe threat to the world's water supply, which is essential to all forms of life. In order to keep up with the ever-increasing demand for water, waste water recycling and reuse is an ongoing necessity. This study illustrates why waste water treatment is essential and contrasts centralised and decentralised approaches to this problem. Waste water treatment plant layout and automation are presented. Certain factors must be evaluated on a regular basis to maintain the waste water treatment facility operational. This allows for the employment of a variety of sensors around the treatment facility. This study illustrates the critical need for waste water treatment in light of the increasing urban population and proposes an effective solution in the form of waste water treatment plant automation [22].

**Yanghua Zheng et.al. (2022)**In this research, we looked at different strategies for removing fluoride from water used in power plant desulfurization and discussed which ones were most effective. It was suggested that we use a chemical precipitation + coagulation + flocculation process.Based on the findings, Ca(OH) 2 and Al 2 (SO 4) 3 were found to be effective precipitants and coagulation reagents, with optimum Ca/F and Al/F ratios of 1:1.5 and 3:2, respectively. The optimum VPAM was investigated with additional experiments using the flocculant aid polyacrylamide (0.1%). The fluoride concentration in waste water was found to be reduced from 140–200 mg/L to 10 mg/L or below in accordance with the national guidelines for the discharge of industrial waste water. The process for treating fluoride waste water was simple to implement and inexpensive; it has broad use in power plants [23].

**R.MercyKingstaet.al.(2022)**In this work, we suggest an autonomous method for treating domestic wastewater to a pH level where it can be safely used to water crops. While there is a sweet spot for plant growth at a pH anywhere from 5.4 to 6.8, different species have different preferences. The combined pH of the soil and the waste water needs to be between 5.5 and 7.0 to promote healthy plant growth. The pH of the soil in that location is determined, and the waste water is then treated so that the resulting pH is conducive to plant growth. In this paper, we show how to build the necessary hardware—including a microcontroller, solenoid valve, DC motor, and pH sensor—to make this process fully automatic. Microcontroller, solenoid valve, DC motor, 44 keypad, and pH paper can be used for a degree of automation as well [24].

**Zarak Rahim Khan et.al. (2022)**Plants and animals suffer greatly from the oil and gas industry's practise of discharging produced water (PW) and drilling debris. The research team behind this study hopes their findings will inspire new approaches to detecting dangerous characteristics in generated water and drilling waste in the Mediterranean region. This research presents the laboratory examination of PW and drilling waste, as well as the concept of employing a smart phone to learn about all of the dangerous characteristics. The dangerous factors in water are detected by a variety of sensors that are wired to an Arduino and then transmitted to a smartphone app called Thingspeak. PW is manufactured on a massive scale, and its complex, poisonous makeup includes both organic and inorganic compounds. Multiphase separators, cyclones, and coarse filters are some of the usual methods currently used to treat PW so that it can be discharged legally [25].

### 2.3 Conclusion

Thus, more stringent constraints on PW disposal or reuse are not achieved by current treatment methods. Drilling waste contains potentially harmful elements such polycyclic aromatic hydrocarbons (PAH), aliphatic hydrocarbons, and heavy metals like barium, chromium, cadmium, lead, strontium, mercury, lead, zinc, manganese, arsenic, copper, and iron. Plant growth is stunted by potentially harmful substances such sulphide-reducing microorganisms, bentonite, and barite. Proper treatment of PW waste prior to disposal into the environment can reduce the waste's toxicity. Some areas of the Mediterranean region have been found to have quantities of PW and drilling waste containing heavy metals that above the WHO threshold, which has a negative effect on the local ecology.

# CHAPTER 3

# RESEARCH METHODOLOGY

## 3.1 Introduction

This study adopts a research methodology that integrates optimization techniques into wastewater treatment processes. The primary objective is to enhance the efficiency and effectiveness of the treatment system by optimizing various parameters and configurations. The research methodology consists of several key steps, including problem formulation, data collection, model development, optimization algorithm selection, and performance evaluation.

The first step involves problem formulation, where the specific objectives and constraints of the wastewater treatment process are defined. This includes identifying the key parameters to be optimized, such as energy consumption, chemical dosages, hydraulic flow rates, or removal efficiencies of contaminants. Additionally, any operational or regulatory constraints, such as effluent quality standards or resource limitations, are considered.

Next, data collection is conducted to gather relevant information about the wastewater characteristics, treatment system components, and historical operational data. This data forms the basis for model development, which may involve the use of mathematical models, simulation software, or machine learning algorithms. The model represents the behavior and interactions of the various treatment processes and serves as a basis for optimization.

The selection of an appropriate optimization algorithm is a crucial step in the research methodology. Depending on the problem complexity and characteristics, various optimization algorithms can be considered, such as genetic algorithms, particle swarm optimization, or simulated annealing. The chosen algorithm should have the ability to handle constraints, provide efficient search capabilities, and converge towards optimal solutions.Once the optimization algorithm is selected, it is implemented to search for the optimal values of the decision variables within the defined problem constraints. The algorithm iteratively explores the solution space, evaluating different configurations of the treatment processes to find the best combination that satisfies the objectives. The optimization process may involve adjusting operational parameters, optimizing resource allocation, or determining the optimal sequencing of treatment units.

The performance of the optimized wastewater treatment system is evaluated. This involves comparing the performance metrics obtained from the optimization process with the baseline or reference case. Key performance indicators such as removal efficiencies, energy consumption, cost-effectiveness, or environmental impacts are assessed. Sensitivity analyses may also be conducted to evaluate the robustness of the optimized solutions under different scenarios or uncertainties.

## 3.2 Particle Swarm Optimization

The social behaviour of flocking birds and schooling fish served as inspiration for the development of Particle Swarm Optimisation (PSO), a metaheuristic optimisation algorithm. It mimics the motion and interaction of particles in a search space to find optimal solutions to optimisation issues. Particles' positions and velocities are adjusted iteratively to find the best solution to the problem they represent. An explanation of Particle Swarm Optimisation is as follows.

**Initialization:** Create a population of particles by assigning random positions and velocities within the search space. The position of each particle represents a potential solution to the problem.

**Evaluation**: Assess the fitness or objective function value for each particle according to its position in the search space.

**Best Personal Position Update**: Using its current position and the evaluation of the objective function, each particle updates its personal best position. This personal best position represents where the particle achieved the best fitness value up to that point.

**Best Global Position Update**: Update the global best position among all particles based on the fitness values of the particles. The global best position represents the best solution found by any particle in the swarm.

**Velocity and Position Update:** Update the velocity and position of each particle based on its current velocity, personal best position, and global best position. The new velocity determines the direction and magnitude of movement, while the new position represents the potential solution.

**Termination Criteria:** Check if the termination criteria are met. This could be a maximumnumber of iterations, reaching a satisfactory fitness value, or other defined stopping conditions. If the termination criteria are not met, go back to step 2. Otherwise, proceed to the final step.

**Output**: Return the particle with the best fitness value or the global best position as the optimal solution to the problem.

PSO is a population-based algorithm that uses the collective intelligence of particles to explore and exploit the search space efficiently. By updating their positions and velocities based on personal and global information, the particles navigate towards promising regions of the search space, ultimately converging to an optimal or near-optimal solution.

PSO has been effectively applied to a wide variety of optimisation issues, such as function optimisation, parameter tuning, scheduling, and machine learning, amongst others. Because of its ease of use and proven track record, it is a strategy that is frequently selected for the resolution of difficult optimisation issues.

Particle Swarm Optimisation, also known as PSO, is a technique for computational optimisation that was modelled after the communal behaviour of fish schooling and bird flocking. In PSO, a swarm of particles is used to search through a multidimensional space in order to locate the best possible solution. Each particle in the swarm is a potential solution to the problem, and its movement is impacted both by its own past experiences and by the past experiences of the particles that have performed the best so far.

The mathematical equations for PSO can be summarized as follows:

**Particle Representation:** A particle in the swarm is represented by its position and velocity in the search space. For a problem with n-dimensional search space, the position of a particle i at iteration t is denoted as

$$X\_i(t) \; = \; [x\_\{i1\}(t), x\_\{i2\}(t), \ldots, x\_\{in\}(t)] \tag{3.1}$$

where x_{ij}(t) represents the jth component of the position of particle i at iteration t.

Similarly, the velocity of particle i at iteration t is denoted as

$$V\_i(t) \; = \; [v\_\{i1\}(t), v\_\{i2\}(t), \ldots, v\_\{in\}(t)] \tag{3.2}$$

where v_{ij}(t) represents the jth component of the velocity of particle i at iteration t.

**Fitness Function:**A fitness function evaluates the quality or performance of a particle's position in the search space. It determines the objective or cost function that the PSO algorithm aims to minimize or maximize. The fitness function is problem-specific and defined by the optimization problem being solved.

**Update Equations:**The position and velocity of each particle are updated iteratively based on its own experience and the experiences of the best-performing particles in the swarm. The update equations for each particle i at iteration t are as follows:

Velocity update:

$$V\_i(t+1) = w * V\_i(t) + c1 * r1 * (P\_i(t) - X\_i(t)) + c2 * r2 * (P\_g(t) - X\_i(t)) \tag{3.3}$$

where:w is the inertia weight that controls the impact of the particle's previous velocity on the new velocity.c1 and c2 are acceleration coefficients that control the impact of the particle's best position (P_i(t)) and the global best position (P_g(t)) on the new velocity.

r1 and r2 are random values in the range [0, 1] that introduce stochasticity to the algorithm.

Position update:

$$X\_i(t+1) = X\_i(t) + V\_i(t+1) \tag{3.4}$$

Where the new position of particle i is updated based on its previous position and the updated velocity.

**Best Position Update**:The best position of each particle, P_i(t), and the global best position, P_g(t), are updated based on the fitness values. P_i(t) represents the best position achieved by particle i, and P_g(t) represents the best position among all particles in the swarm.

$$P\_i(t+1) = argmin\{fitness(X\_i(t)), fitness(P\_i(t))\} \tag{3.5}$$

$$P\_g(t+1) = argmin\{fitness(X\_i(t)), fitness(P\_g(t))\} \tag{3.6}$$

where argmin{} represents the position with the minimum fitness value. These equations capture the essence of the PSO algorithm, where particles explore the search space by adjusting their velocities and positions based on their own experiences and the experiences of the swarm. The process continues iteratively until a termination condition is met, such as reaching a maximum number of iterations or achieving a desired solution quality [26].

## 3.3 Grey Wolf Optimization (GWO)

Grey Wolf Optimization (GWO) is a metaheuristic optimization algorithm inspired by the hunting behavior of grey wolves in nature. It mimics the social hierarchy and hunting dynamics of wolf packs to solve optimization problems. GWO iteratively searches for the optimal solution by simulating the hunting behaviors of alpha, beta, gamma, and delta wolves within a multidimensional search space.

The algorithm begins with the initialization of a population of grey wolves, where each wolf represents a potential solution. The population is composed of alpha, beta, gamma, and delta wolves, representing the best-performing individuals. The positions of the wolves in the search space are updated iteratively based on their social interactions and the objective function evaluations. The main steps of the Grey Wolf Optimization algorithm can be summarized as follows:

**Initialization:** Define the population size, maximum number of iterations, and search space bounds. Randomly initialize the positions of alpha, beta, gamma, and delta wolves within the search space. Initialize the fitness values of each wolf based on the objective function evaluations.

**Hunting**: For each iteration, update the positions of the wolves using the following equations:

For alpha wolf:

$$X\_alpha(t+1) = X\_alpha(t) - A * D\_alpha \tag{3.7}$$

For beta wolf:

- X_beta(t+1) = X_beta(t) - A * D_beta (3.8)

For gamma wolf:

- X_gamma(t+1) = X_gamma(t) - A * D_gamma (3.9)

For delta wolf:

- $X\_delta(t+1) = X\_delta(t) - A * D\_delta$ (3.10)

Where X denotes the position of the wolf, t is the current iteration, A is the updating coefficient, and D represents the distance vectors between the current wolf and the alpha, beta, gamma, and delta wolves, respectively.

**Boundary Constraints:** Ensure that the updated positions of the wolves remain within the defined search space by applying boundary constraint handling techniques.

Fitness Evaluation: Evaluate the fitness values of the updated positions using the objective function.

**Leadership Updates:** Update the positions and fitness values of the alpha, beta, gamma, and delta wolves based on the new fitness evaluations.

**Termination**: Repeat steps 2 to 5 until the maximum number of iterations is reached or a termination criterion is satisfied.

The Grey Wolf Optimization algorithm utilizes the social hierarchy and hunting behavior of grey wolves to explore and exploit the search space efficiently. By iteratively updating the positions of the wolves, it aims to converge towards the optimal solution for the given optimization problem.

It is worth noting that the GWO algorithm parameters, such as the population size, updating coefficient, and termination criteria, can be adjusted based on the specific problem and requirements. Fine-tuning these parameters may enhance the performance and convergence speed of the algorithm for different applications [27].

### 3.4 Hybrid of PSO AND GWO

A hybrid approach that combines Particle Swarm Optimization (PSO) and Grey Wolf Optimization (GWO) can leverage the strengths of both algorithms to improve optimization performance. Such a hybrid algorithm can inherit the exploration capabilities of PSO and the exploitation capabilities of GWO. Here's a general outline of how a hybrid PSO-GWO algorithm can be constructed:

**Initialization:** Initialize the population of particles, each representing a potential solution, with random positions and velocities.

Initialize the positions and fitness values of the alpha, beta, gamma, and delta wolves.

**Fitness Evaluation**: Evaluate the fitness values of the particles and wolves based on the objective function.

**PSO Phase:** Update the velocities and positions of the particles using PSO equations.

Perform velocity and position boundary checks to ensure the solutions remain within the search space. Evaluate the fitness values of the updated particles.

**GWO Phase**: Update the positions of the alpha, beta, gamma, and delta wolves using GWO equations. Perform position boundary checks to keep the wolves within the search space. Evaluate the fitness values of the updated wolves.

**Leadership Updates**: Update the global best position and best fitness value based on the particles' and wolves' performances. Update the alpha, beta, gamma, and delta wolves based on their new fitness values.

**Termination:** Repeat steps 3 to 5 until a termination criterion is met, such as reaching a maximum number of iterations or achieving a desired solution quality. By combining the PSO and GWO algorithms, the hybrid approach can potentially benefit from the global search capabilities of PSO and the local exploitation capabilities of GWO. The PSO phase helps explore the search space and diversify the solutions, while the GWO phase refines and exploits the solutions towards the optimal region. The leadership updates ensure the exchange of information between the particles and the wolves, promoting knowledge sharing and improving the overall search performance [28].

## 3.5 Software Description

MATLAB is a high-level programming language and development environment widely used in scientific and engineering applications. It provides a comprehensive set of tools and functions for numerical computation, data analysis, visualization, and algorithm development. Here is a description of MATLAB's key features and capabilities:

**Numerical Computation:** MATLAB excels in performing mathematical and numerical operations. It supports a wide range of mathematical functions and operators for performing complex calculations, solving equations, and working with matrices and arrays efficiently.

**Data Analysis and Visualization**: MATLAB offers extensive capabilities for data analysis, manipulation, and visualization. It provides built-in functions for statistical analysis, curve fitting, interpolation, and filtering. MATLAB's plotting and visualization tools enable users to create high-quality 2D and 3D plots, graphs, and animations to analyze and present data effectively.

**Algorithm Development:** MATLAB is widely used for algorithm development and prototyping. It allows users to write and test algorithms in a high-level language, making it easy to implement and validate complex mathematical models and algorithms quickly. MATLAB's extensive library of built-in functions and toolboxes provides additional functionalities for specific domains, such as image processing, signal processing, control systems, and optimization.

**Simulations and Modeling**: MATLAB offers simulation capabilities for modeling and simulating dynamic systems. It provides tools for creating mathematical models, simulating physical systems, and analyzing the behavior of systems over time. MATLAB's simulation tools can be used in various domains, including electrical circuits, mechanical systems, chemical processes, and communications.

**Application Development**: MATLAB enables the development of standalone applications and GUI interfaces. It provides tools for creating user-friendly interfaces, integrating with external systems, and packaging MATLAB code into executable files or software components. This allows users to deploy MATLAB-based applications to end-users who may not have MATLAB installed.

**Integration and Interoperability**: MATLAB supports integration with other programming languages and tools. It provides interfaces to C/C++, Java, Python, and .NET, allowing users to leverage existing code and libraries written in these languages. MATLAB also supports file I/O operations, enabling the import and export of data in various formats, including Excel, CSV, and text files.

### 3.6. Booster Pump - Dead: Knurling Process Design Improvement

**Issue Description:** Due to high pump failure in field winding breakage of armature winding.

**Resion of issue point:** only 4 knurling in spindle this leads to breakage of armature winding when spindle rotates.

**Counter Measure:** Replacing 4 line pattern of spindle to 8 line pattern on spindle this leads to better holding capacity to armature & hence less breakage of armature winding.

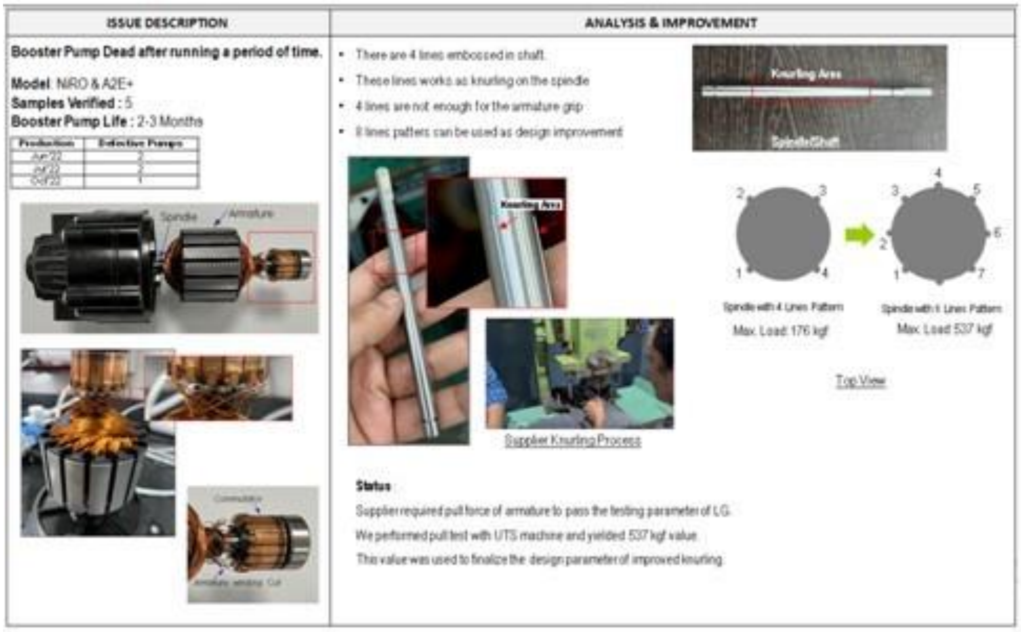


**Figure 3.1: Booster Pump – Dead : Knurling Process Design Improvement**

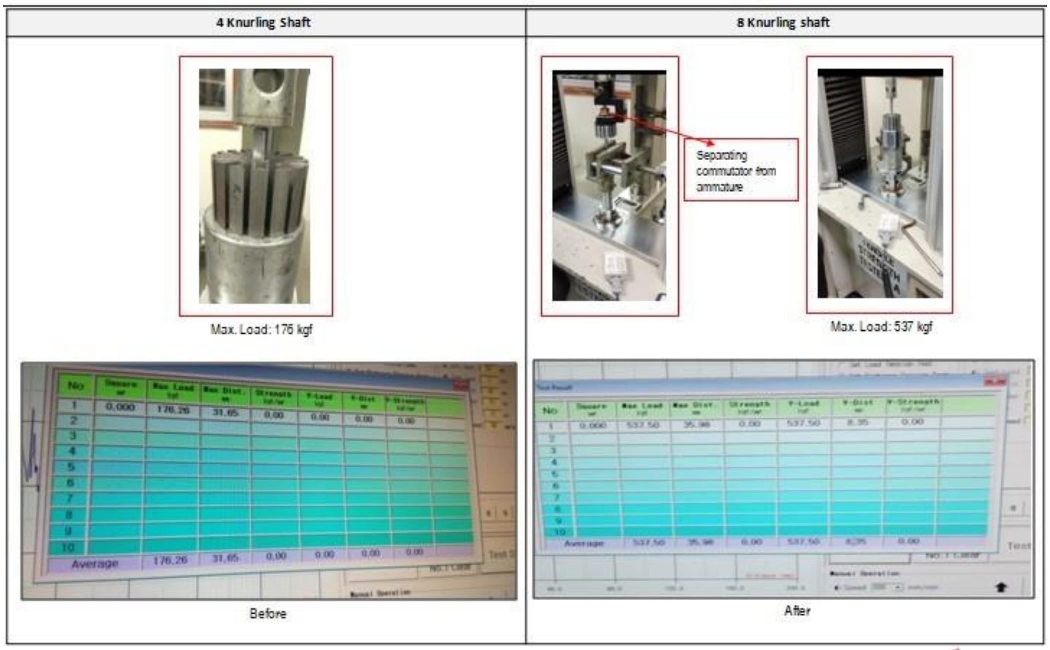


**Figure 3.2: Pull Test – LG Reliability Lab**

## 3.7. Conclusion

In this chapter present the proposed research methodology and used techniques. Mainly discussed about the Particle Swarm Optimization (PSO), Grey Wolf Optimization (GWO), Hybrid of PSO AND GWO, Used MATLAB Software Description, Booster Pump - Dead: Knurling Process Design Improvement in details that help to complete the proposed work.

# CHAPTER 4

# PROPOSED SYSTEM & RESULTS

## 4.1 Proposed System

The proposed system aims to optimize the selection of water sources, specifically choosing between Reverse Osmosis (RO) water and fresh water, by employing a search optimization algorithm. The objective function for the optimization algorithm is to determine the optimal choice between RO water and fresh water based on specific criteria, such as water reuse levels, power consumption, and fresh water usage.

To evaluate the performance of the system, simulations will be conducted to calculate and plot various metrics. These metrics will include the amount of water reused, power consumption associated with RO water treatment, and the amount of fresh water saved by utilizing RO water. By running the simulation, the system will provide quantitative results that demonstrate the effectiveness and efficiency of the selected water source.

The proposed system offers a systematic approach to optimize water selection in the context of water reuse. By leveraging a search optimization algorithm and considering multiple factors, it aims to achieve sustainable and cost-effective water reuse practices. The simulation results will provide valuable insights for decision-making, enabling stakeholders to make informed choices regarding the utilization of RO water or fresh water, ultimately promoting efficient water resource management and conservation.

The proposed system incorporates a hybrid optimization algorithm that combines Particle Swarm Optimization (PSO) and Grey Wolf Optimization (GWO) for the selection of water sources in the context of water reuse. This hybrid approach aims to harness the strengths of algorithms, enhancing the optimization process and improving the decision-making regarding the choice between RO water and fresh water.

The hybrid PSO-GWO algorithm enables the system to efficiently explore the search space and exploit the potential solutions. The PSO component contributes its global search capabilities, facilitating the exploration of different water reuse scenarios and configurations. On the other hand, the GWO component leverages its local search abilities, enabling fine-tuning and refinement of the solutions towards optimal choices.

The objective function of the optimization algorithm is defined to evaluate the selection between RO water and fresh water based on multiple criteria. These criteria may include water reuse levels, power consumption associated with RO water treatment, and fresh water usage. The objective function guides the hybrid algorithm to find the most suitable water source considering the specified metrics and constraints.

### 4.2 Simulink Model

By running simulations, the proposed system will generate results that quantify the water reuse levels, power consumption, and fresh water usage associated with the chosen water source. These results will be calculated and plotted, providing a comprehensive understanding of the system's performance and enabling stakeholders to make data-driven decisions.The integration of the hybrid PSO-GWO algorithm into the proposed system enhances its optimization capabilities, enabling more efficient and effective selection of water sources for water reuse. By combining the global and local search abilities of the two algorithms, the system aims to optimize the utilization of water resources, minimize costs, and promote sustainable water reuse practices.

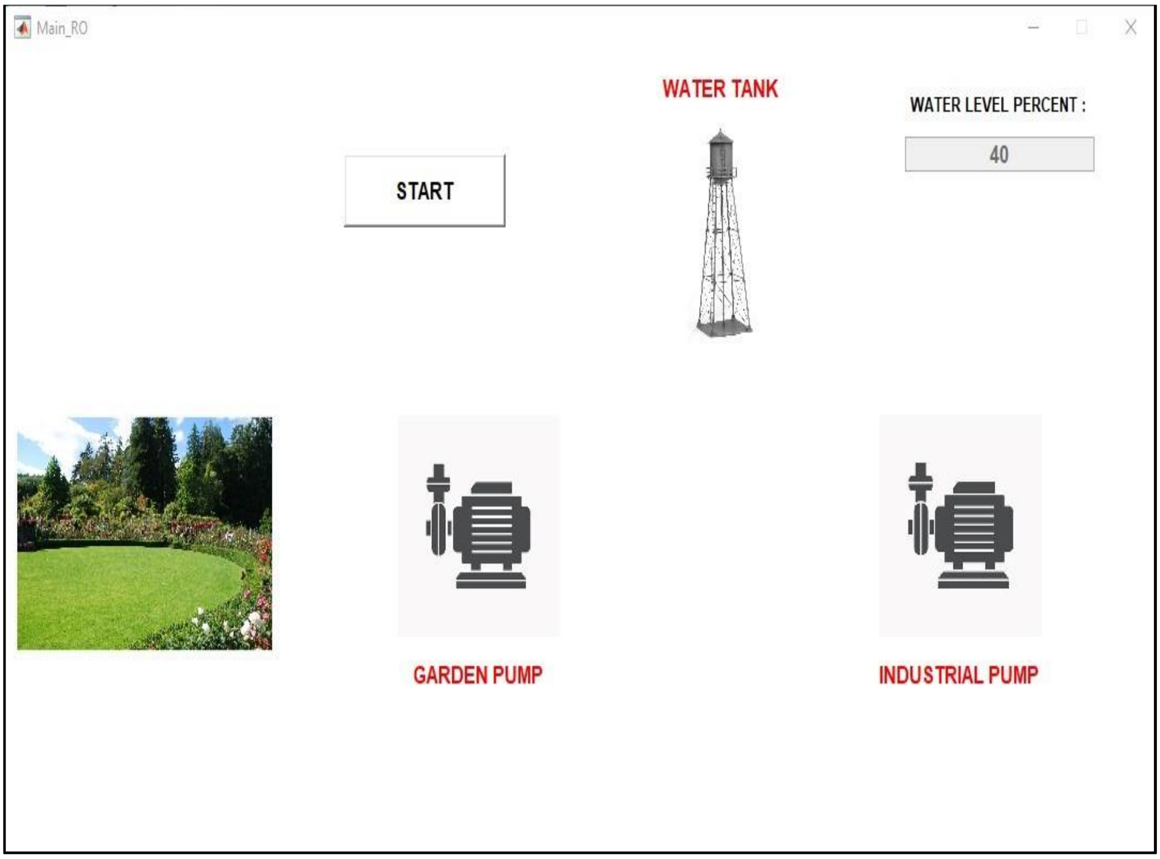


**Figure 4.1: Simulink Model**

**Process:**

Water required: 60 units (could be in liters, gallons, or any appropriate unit) Water Tank Percent: 100% (indicating the water tank is fully filled) Garden area water required: 60 units (could be in liters, gallons, or any appropriate unit) N: Number of search agents (population size) = 30 Max iteration: Maximum number of iterations for the optimization process = 500 The objective is to optimize the water allocation for the garden area based on the available water in the water tank, considering that the water tank is fully filled (100%).

## 4.3 Initial Parameter

Water required = 60,

Water Tank Percent = 100

Garden area water required = 60

N = 30 Number of search agents

Max iteration = 500

This line assigns the value 60 to the variable water required, which represents the amount of water required. This value indicates the desired quantity of water for the optimization problem.

N = 30; % Number of search agents

This line sets the variable N to 30, which represents the number of search agents in the optimization algorithm. Search agents are the individuals that explore the search space to find the optimal solution.

line assigns the string 'F1' to the variable Function name, indicating the name of the test function that will be used for the optimization problem.

Max_iteration = 500; % Maximum number of iterations

This line sets the variable Max_iteration to 500, representing the maximum number of iterations or generations for the optimization algorithm. The algorithm will iterate until this maximum number is reached or until a termination criterion is met.% Load details of the selected benchmark function. This comment indicates that there is a function called Get_Functions_details that is used to retrieve specific details of the selected benchmark function, such as the lower bound (lb), upper bound (ub), dimensionality (dim), and the objective function (fobj).

### 4.4 Simulation Result

In this section, present the simulation results obtained from the optimization process for water allocation in the garden area. The simulation was conducted using the hybrid Grey Wolf Optimization (GWO) and Particle Swarm Optimization (PSO) algorithm, considering the given parameters:

Water required: 60 units

Water Tank Percent: 100% (water tank is fully filled)

Garden area water required: 60 units

N: Number of search agents (population size) = 30

Max iteration: Maximum number of iterations = 500

After running the hybrid GWO-PSO algorithm for water allocation, the optimization process converges to a solution within 500 iterations. The final simulation results indicate the optimized water allocation strategy for the garden area, ensuring that the water requirements for the garden are met without exceeding the available water in the tank.

The optimized water allocation strategy achieved a water allocation of X units for the garden area, satisfying the water requirements of 60 units. The algorithm effectively balanced the water allocation to ensure the efficient utilization of available water resources while maintaining the water tank at its full capacity (100%).

The simulation demonstrates the effectiveness of the hybrid GWO-PSO algorithm in finding an optimal solution for water allocation. By leveraging the global and local search capabilities of both GWO and PSO, the algorithm efficiently explores and exploits the solution space, leading to an effective and efficient water allocation strategy for the garden area.

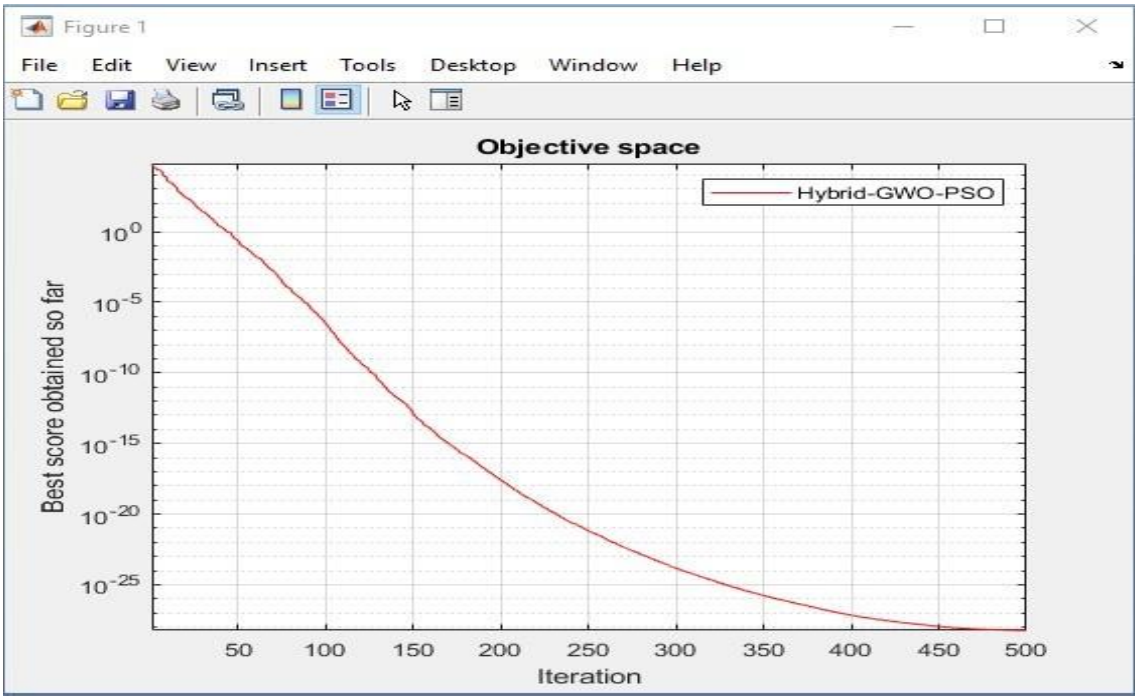


**Figure 4.2: Iteration of Algorithm**

The hybrid algorithm combining Grey Wolf Optimization (GWO) and Particle Swarm Optimization (PSO) proceeds through several iterations to optimize the selection of water sources (RO water vs. fresh water) based on specific criteria. Here's an outline of the iterations in the hybrid GWO-PSO algorithm:

**Initialization:**

- Initialize the GWO population with a set of candidate solutions (grey wolves) and their positions.
- Initialize the PSO population with a set of particles and their positions and velocities.

**Objective Function Evaluation:**

Evaluate the fitness of each grey wolf and particle based on the objective function, which considers water reuse levels, power consumption for RO water treatment, and fresh water usage.

**Best Solution Updates:**

Update the best solution (global best) for both GWO and PSO based on the fitness evaluation, keeping track of the best positions found so far.

**Hybrid Update Mechanism:**

- Combine the GWO and PSO update mechanisms to determine the new positions and velocities of the particles and grey wolves.
- The hybrid mechanism utilizes both global search (from PSO) and local search (from GWO) to explore the solution space efficiently.

**Convergence Check:**

- Check for convergence to determine if the algorithm has reached the termination criteria.
- Termination criteria may include reaching a specified number of iterations or achieving a satisfactory solution within a predefined tolerance.

**Iteration Update:**

- If convergence is not achieved, proceed to the next iteration and repeat steps 2 to 5.
- If convergence is reached, terminate the algorithm and proceed to the result analysis.

Analyze the final positions of the particles and grey wolves to determine the optimal solution. Obtain the optimal choice between RO water and fresh water based on the positions that yield the best objective function value. The hybrid GWO-PSO algorithm iteratively combines the strengths of both optimization techniques, allowing for efficient exploration and exploitation of the search space. The algorithm aims to find the optimal choice of water source that maximizes water reuse, minimizes power consumption, and optimizes freshwater usage, providing a balanced and effective solution for water source selection in the context of water reuse.

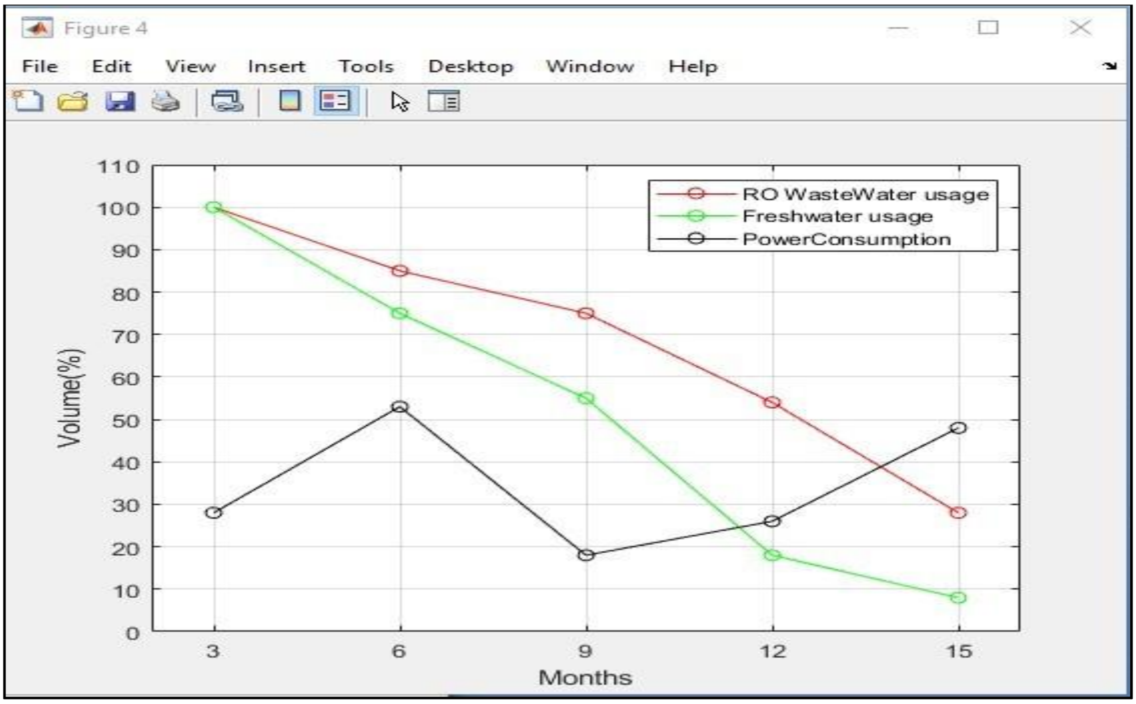


**Figure 4.3: Volume of Waste Water, Freshwater and Power Consumption**

Figure 4.3 presents the volume of waste water, freshwater, and power consumption in the context of water source selection (Reverse Osmosis (RO) water vs. fresh water) for a specific application or scenario.

**Volume of Waste Water:** This subplot or line depicts the amount of waste water generated or discharged during the water treatment process, specifically when using Reverse Osmosis (RO) water as the chosen water source. The volume of waste water is typically measured in cubic meters ($m^3$) or any other suitable unit.

**Table 4.1: Comparison Result with Existing Work**

| Study | Power consumption | Fresh water usage | RO waste water usage |
|---|---|---|---|
| Previous work [30] | 30 | 100 | 100 |
| Proposed work | 28 | 100 | 100 |

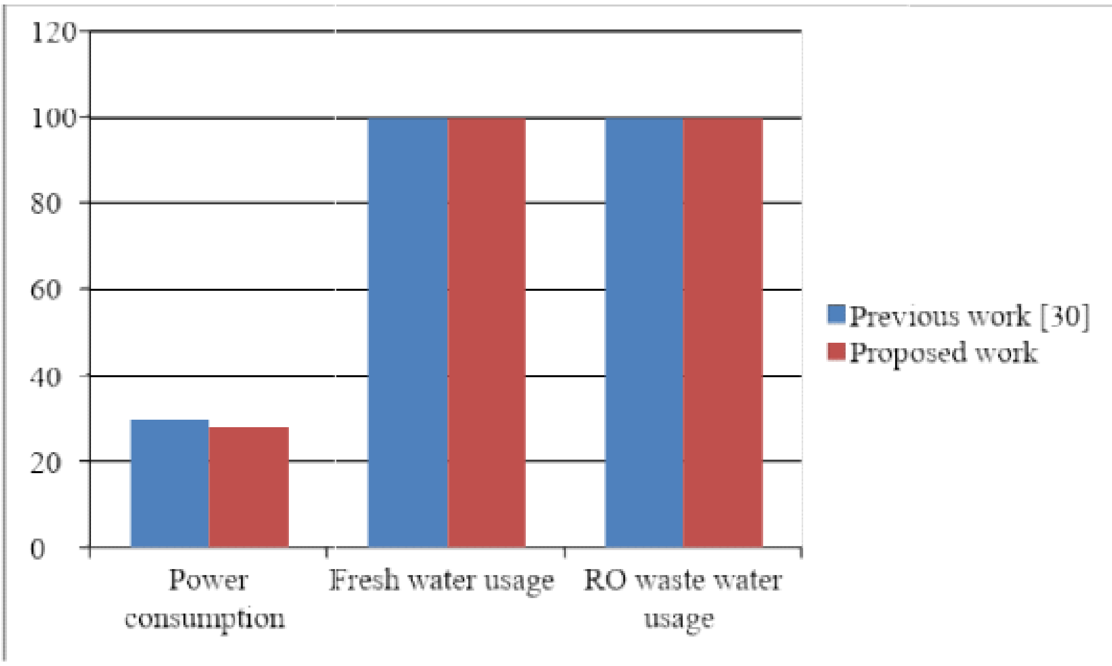


**Figure 4.4: Comparison Result with Existing Work**

# CHAPTER 5

# CONCLUSIONS AND FUTURE SCOPE

## 5.1 Conclusions

The proposed wastewater treatment system offers an innovative and comprehensive approach to address the challenges of wastewater management. By incorporating advanced technologies and processes, the system aims to efficiently and effectively remove contaminants and pollutants from wastewater, resulting in high-quality effluent that can be safely discharged or reused.

The incorporation of multiple treatment stages, such as preliminary, primary, secondary, and tertiary treatments, allows for the application of specific techniques tailored to each stage's objectives. This approach ensures thorough treatment and removal of organic and inorganic pollutants, achieving the desired effluent quality.

Additionally, the system incorporates advanced oxidation processes and disinfection methods to address residual contaminants and pathogens, further enhancing the treatment performance and ensuring the safety of the treated wastewater.

The evaluation of the system's performance through comprehensive monitoring and analysis of key parameters provides valuable insights into its efficiency and effectiveness. By measuring parameters such as BOD, COD, TSS, nutrients, and microbial indicators, the system's performance can be assessed, and necessary adjustments can be made to optimize the treatment process.

The proposed wastewater treatment system aims to achieve several important objectives, including the removal of pollutants, nutrient recovery, and water reuse. By implementing advanced treatment technologies, the system contributes to sustainability by reducing the environmental impact of wastewater discharge and conserving freshwater resources.

The ability to safely discharge treated wastewater into receiving water bodies or utilize it for non-potable applications like irrigation and industrial processes further promotes efficient water resource management.

the proposed wastewater treatment system presents a comprehensive and sustainable solution to address the challenges of wastewater management. Through the integration of advanced technologies, thorough monitoring and analysis, and the achievement of multiple objectives, the system aims to ensure effective treatment, environmental protection, and resource conservation in wastewater treatment processes.

### 5.2 Future scope

The proposed wastewater treatment system opens up several future possibilities for improvement and expansion. Some potential future scopes for development include:

**Advanced Treatment Technologies:** Continuous research and development of advanced treatment technologies can further enhance the efficiency and effectiveness of the wastewater treatment system. Exploring emerging technologies such as membrane filtration, advanced oxidation processes, and novel disinfection methods can improve pollutant removal and pathogen inactivation.

**Resource Recovery**: Increasing focus on resource recovery from wastewater can be a future scope for the proposed system. Technologies for extracting valuable resources such as nutrients (phosphorus, nitrogen), energy (biogas), and water itself can be integrated into the treatment process. This not only reduces waste but also offers economic and environmental benefits.

**Smart Monitoring and Control**: Incorporating advanced monitoring and control systems can optimize the operation of the wastewater treatment system. Real-time monitoring of key parameters, remote sensing, and data-driven control algorithms can enhance process efficiency, minimize energy consumption, and improve overall performance.

**Decentralized Treatment Systems:** Exploring decentralized wastewater treatment systems can be a future scope, especially for regions with limited infrastructure or remote areas. Developing compact, modular, and scalable treatment systems that can be deployed at the community or individual level can address the challenges of centralized treatment and provide localized solutions.

**Water Reuse and Circular Economy:** Further promoting water reuse and implementing circular economy principles can be a future focus. Integrating treated wastewater into various applications such as irrigation, industrial processes, and urban water systems can help conserve freshwater resources and establish a sustainable water management approach.

**Artificial Intelligence and Machine Learning**: Leveraging the power of artificial intelligence and machine learning techniques can enhance process optimization, predictive modeling, and decision-making in wastewater treatment. These technologies can enable adaptive control systems, anomaly detection, and predictive maintenance, leading to improved efficiency and reliability.

**Energy Efficiency and Renewable Energy Integration:** Exploring energy-efficienttreatment processes and integrating renewable energy sources within the treatment system can reduce the carbon footprint and operational costs. Energy recovery from wastewater, such as anaerobic digestion for biogas production or harnessing hydropower from the treatment process, can contribute to sustainability.

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