

Title in English

**The Impact of Water Recycling on the Operational and Environmental
Performance of Facilities in the Haramain High Speed Train Project**

Title in Arabic

أثر إعادة تدوير الماء على الأداء التشغيلي والبيئي للمنشآت في مشروع قطار الحرمين السريع

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المخلص

في المملكة العربية السعودية، مع تزايد التنمية السكانية، تتزايد الحاجة إلى مياه الشرب الآمنة للاستخدام البشري والتطبيقات الحديثة. يهدف هذا البحث إلى إظهار معالجات المياه المطبقة في المنشآت ونتائجها وأيضاً بيان أهمية هذه الأنظمة تجاه الأزمات البيئية التي يطبقها مشروع قطار الحرمين السريع. يتم فحص الروابط بين إعادة استخدام المياه والمياه الصالحة للصيانة في المشروع. إن إعادة استخدام المياه والحفاظ عليها لها أثر إيجابي كبير على البيئة لأنها تقلل من كمية المياه العذبة المحولة والآثار السلبية لتصريف مياه الصرف الصحي على نوعية المياه في البيئة. تم تقديم عدد قليل من النماذج التي توضح المزايا الطبيعية من الناحية الكمية. كما تصور الورقة المزايا المالية والبيئية المميزة في مختلف مراكز دورة المياه المنسقة المتأخرة في مشروع قطار الحرمين السريع.

Abstract

In Saudi Arabia, as populace development builds, the requirement for safe drinking water is increasingly expanding for both human use and modern applications. This research aims to Show the applied water treatments in facilities and their results and also, show the importance of these systems towards the environmental crises that are applied by Haramain High Speed Train project. The connections between water reuse and maintainable water in the project are inspected. Reusing and conserving water have a significant positive impact on the environment because they reduce the amount of freshwater diverted and the negative effects of wastewater discharges on the environment's water quality. A few models are introduced showing the natural advantages in quantitative terms. The paper likewise depicts the financial and ecological advantages distinguished in various late coordinated water cycle arranging concentrates on the Haramain High Speed Train project.

Keywords: *Water Treatment Plant •Quality Tools •Operational Procedure. Haramain High Speed Train project*

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Introduction

Kingdom of Saudi Arabia (KSA) covers an area of around 2.25 million km² situated in dry and hyper parched district has restricted sustainable freshwater assets with no perpetual waterways or extremely durable freshwater bodies. KSA is viewed as one of the driest regions because of low precipitation and high Evapotranspiration rates. After the discovery of oil holds in right on time of 1950, KSA has seen exceptional monetary treatment and fast expansion in its populace in the beyond forty years. The number of inhabitants in KSA expanded from under 4 millions of every 1960 to more than 32.5 million out of 2018. The population is supposed to arrive at more than 56 million by 2050 (International Union of Railways, 2022).

KSA launched an ambitious agricultural development program in the 1980s with the goal of increasing its agricultural production and food self-sufficiency. Groundwater over deliberation from the non-sustainable spring frameworks, brought about significant decreases in groundwater levels and deuterium apportion in groundwater quality (Arzaghi & Henderson, 2008)

Ways of behaving, for example, water supply-based approaches, expanding populace development, and horticultural strategies, urbanization, and rising living standards prompted impractical scant freshwater use, KSA has restricted non-inexhaustible groundwater hold with exceptionally restricted re-energize rates to sustainable groundwater spring frameworks. The domestic sector in KSA uses approximately 8.5 million cubic meters of water each day, even though renewable freshwater resources are extremely scarce. While the worldwide typical inexhaustible water asset per capita each year is 6,000 m³, KSA has just 84.8 m³/cap/y (Arzaghi & Henderson, 2008).

Notwithstanding the water shortage, Saudi Arabia has the third most noteworthy water utilization per capita at 250 l/cap/d. The nation's water request is supposed to increment by 56% by 2035. In the meantime, ground water aquifers are only expected to supply potable water for the

next 10 to 30 years at the current rate of water withdrawal. The water sector in Saudi Arabia has recently been confronted with several issues that pose a threat to water, food, and energy security. Fuel endowments and desalinated water creation exhaust the country energy assets alongside resulting ecological expense, low water taxes, and the expanded spillage from central conduits transmission and dissemination organizations. These elements influence drinking water and wastewater creation and treatment costs (Arzaghi & Henderson, 2008)

Economic improvement in KSA is confronting the difficulties of sustainable freshwater assets shortage and the consistently in-wrinkling water interest. KSA is ranked as the first largest producer of desalinated water with an annual desalination capacity of nearly 2,500 million m³, or about 30% of the world's capacity. Nonetheless, desalinated water alone cannot supply sufficient freshwater to meet the rising future water interest. Just 10% of the all-out wastewater produced as of now being reused. The projected development and change in water portfolios offer colossal chances to coordinate novel methodologies of water recovery and reuse. Late statis-spasm in 2018 showed that the volume of treated wastewater used to create freshwater in KSA was roughly 390 million cubic meters each year. The measurement likewise indicated that the working income from sewerage area in KSA in 2018, was 629 million U.S. dollars. The key difficulties confronting KSA wastewater area are the substantial development in wastewater administration's request; low inclusion of existing wastewater assortment frameworks, treatment facilities, expanding the usage and reuse proportion and the required legislative capital interest in wastewater foundation improvement) Kajenthira, et al., 2012).

Water recycling is considered an efficient strategy to conserve water resources, reduce water demand, and minimize the environmental impact of water consumption. Many regions worldwide face water scarcity issues, so the world nations prioritize water conservation. The

development of the water treatment process to reuse the water demonstrates its advantages. The environmental advantage from reductions in water diversions and the less of wastewater affect towards the environmental water quality. (Kajenthira, et al., 2012). Certainly, there are challenges of water recycling involved with the high treatment cost, the required space for this system, and the potential toxicity of the treated water. Therefore, this research aims to study the impact of water recycling and its positive effects on the facilities performance.

Research Problem:

The research problem is the increased percentage of wastewater in facilities, which raises environmental problems. Therefore, it led to the theory of recycling this wastewater as a solution to decrease environmental pollution and the inefficiency of facility performance.

We summarize the research problem in a central question:

- How advantageous recycling water will be?

The Sub-questions of the research problem:

- What are the types of water recycling?
- What are the benefits of water recycling?

Research Importance:

The research's importance lies in providing a clear understanding of the various procedures of water recycling methods applied in facilities, and their beneficial impact environmental and operational wise.

Research Hypotheses

Implementing water recycling systems in facilities will lead to improved operational efficiency and reduced environmental impact.

Research Goals:

- Showing the applied water treatments in facilities and their results.
- The importance of these systems towards the environmental crises.

Previous studies:

- Garcia et al, (2018) study found that, implementing water recycle systems in food processing industries, plus their impact on the environmental sustainability. This study pointed the amount of water reserves that can be conserve, enhance process efficiency, and lower the environmental effects of water use and wastewater discharge (Garcia et al, 2018)
- Smith et al, (2019) prove that the results of installing water recycling systems in public buildings and commercial facilities, such as offices, hotels, and shopping centers. Also, the researchers evaluated the aftermath of these systems, especially when there is a large number on these facilities. There was a huge reduction in the water demand, which this considered an excellent saving of water resources. The financial savings from bringing down utility costs. Setting a better standard of sustainable credentials for all buildings (Smith et al, 2019)
- Lee et al (2020) indicate that, Researcher looked on the relationship of applying water reprocessing with manufacturing facilities. The research pointed out the fact there is an annual consumption of fresh water by 18.2 billion gallons per day. (Lee et al , 2020)

Assessing operational and environmental impacts of water recycling on the following points: By measuring water usage, which was 40% reduction. By the cost saving, there is a significant saving of up to 7.3 billion gallons per day. The positive impact towards environment by reducing the wastewater and saving the energy. (Lee et al , 2020)

- Apostolidis (2011) Based on the seriousness of this matter to Australia since it is the driest inhabited continent on earth. Water recycling has become a mainstream for most developments. The barriers have been removed to use recycled water for firefighting, toilet flushing, and cooling towers. (Apostolidis , 2011)

The degree of wastewater treatment—primary, secondary, and tertiary—determines the various ways wastewater can be reused. The tertiary level treated wastewater is liberated from all wellbeing dangers and can be utilized to inundate all yields. The optional level treated wastewater is appropriate for nursery blossoms and palm trees, cotton, vegetables however ought not be utilized for dairy cattle raising with milk or meat. The essential level treated wastewater must be utilized for lumber trees in the wake of going to severe preparatory lengths like separated cultivates and forestalling direct contact of laborers with the water. There are numerous obstructions confronting the treated wastewater reuse including innovative, institutional, ecological, financial, and social (public acknowledgment) boundaries. Furthermore, it is essential to create an eco-nomically feasible model for the concerned partners, to guarantee the inescapable supported reception of this system. sums up dangers to be thought about while choosing reuse applications. Definite reviews of the neighborhood situation will want to have the option to survey genuine dangers and limitations, and to choose the most fitting innovation and appropriate gamble avoidance measures. In the subsequent stage, these dangers will be contrasted, and the advantages connected with the utilization of wastewater reuse. Many variables settle on feasibility of reuse projects on the grounds that such tasks require the foundation or change of existing infra-structure, change in water use propensities, and so forth. To settle on feasibility of reuse projects, a more point by point assessment of uses ought to cover

reasonableness of soils and yields, ecological and wellbeing gambles with need for extra infra-design and public acknowledgment of reuse (Apostolidis , 2011)

Comments on Previous Studies:

The consideration of multiple factors such as population growth, urbanization, and climate change, where it will be more necessary to find water sources. There will be more pressure for water recycling. The benefits will be better utilization of water resources, efficient cost saving, and less negative impact on the environment.

Objectives, assumptions, and methodology

The methodology used is observing the built-in systems and analysing their results. Also, the data acquisition sources from the Haramain High Speed Train Project.

- The research uses a descriptive method where it will study the impact of the installed water recycling system. Case study of a KAEC train station.

The study population and sample type will be conducted based on interviews with station management and employees.

Data

Methodology of the Study:

The research method, which is the descriptive analytical method, was used to answer the research question.

The research will be limited to the grey water system in one train station in KAEC city, from 2018 to 2023.

Data collection

Secondary sources: books and scientific articles, and the Primary sources: It is the questionnaire prepared by the researcher and the results were extracted from it to achieve the objectives of the research.

Statistical analysis of the study data:

The interview questions were reviewed, encoded, transcribed, and their data analyzed by computer and by using the Statistical Packages for Social Sciences (SPSS) program to process the study data statistically through:

- 1- Calculating frequencies and percentages to extract a standard descriptive image and analyzing the information considering the objectives and questions of the study. for each paragraph of the interview.
- 2- chi-square test to test the significance of differences between means.
- 3- The validity of the internal consistency of the tool was also extracted by calculating the Pearson correlation coefficient between each item of the tool and the total score of the scale.

Results and Analysis:

Table 1: Sample Demographic Characteristics

Variable	Categories	%
Age	18 – 24	18
	25 – 29	15
	30 – 39	41
	40 – 49 and above	22
Gender	male	54
	female	46
Education level	High School	10
	Bachelor's degree	60
	Master's degree and PhD	30
Major	Engineering	16
	Health Care	10
	Administration	21
	Science	20
	other	33
Working Field	Maintenance	26
	Management	16
	Operation	8
	Commercial	14
	Other	36

The above table show that, most of them are 30 – 39 years around 41% and around 54% were male and 60% having bachelor's degree. In addition, most of them with Administration major and Maintenance around 26%

Table 2: Description of the responses of The Impact of Water Recycling on the Operational and Environmental Performance of Facilities

n	Question	Standard deviation	mean					
				Strongly agree	Agree	Neutral	Disagree	Strongly disagree
1.	Recycled water is a viable solution for conserving freshwater resources	0.5	3.4	77%	14%	2%	3%	4%
2.	Using recycled water for toilet flushing can help reduce overall water consumption	0.3	2.85	78%	14%	4%	2%	2%
3.	Recycled water is safe and poses no health risks when used for toilet flushing	0.1	3.1	79%	14%	3%	2%	2%
4.	The use of recycled water for irrigation in landscapes is an effective way to conserve water	0.7	3.2	78%	14%	4%	2%	2%
5.	Recycled water is suitable for maintaining the health and vitality of plants in landscapes	0.5	3.4	78%	14%	4%	2%	2%
6.	The use of recycled water for street washing can help reduce the demand for freshwater sources	0.3	2.85	79%	12%	6%	2%	3%
7.	Recycled water is a cost-effective alternative to using freshwater for street washing	0.1	3.1	79%	13%	4%	2%	3%
8.	The implementation of recycled water systems for toilet flushing, irrigation, and street washing can contribute to sustainable water management practices	0.7	3.2	78%	13%	4%	2%	3%
9.	Public awareness and education about the benefits and safety of recycled water are essential for its widespread acceptance	0.5	3.4	80%	12%	5%	1%	2%
10.	Government incentives and policies should be implemented to encourage the use of recycled water for toilet flushing, irrigation, and street washing	0.3	2.85	78%	13%	6%	2%	2%

The above results show that most of participants Strongly agree 77% also, Using recycled water for toilet flushing can help reduce overall water consumption around 78% agree with that, third question which is Recycled water is safe and poses no health risks when used for toilet flushing most of them agree with that around 78%, also the researcher and pervious study agree with that as Microbial pathogens in wastewater from sewage effluent are the major concern for human health when recycling water.

79% of participants agree with Recycled water is safe and poses no health risks when used for toilet flushing. And 80% agree with that, public awareness and education about the benefits and safety of recycled water are essential for its widespread acceptance, and the pervious studies agree with that, as Water Recycling Can Decrease Diversion of Freshwater from Sensitive Ecosystems. Water Recycling Decreases Discharge to Sensitive Water Bodies. Recycled Water May Be Used to Create or Enhance Wetlands and Riparian (Stream) Habitats. Water Recycling Can Reduce and Prevent Pollution.

Discussion:

The Kingdom's Vision 2030 framework, in addition to the state's other programs and policies, provides a solid foundation for implementing the sustainable development agenda. In the context of the analyzes that were conducted for the purpose of preparing this review, an evaluation was conducted to measure the extent to which the vision's objectives are related and aligned with the seventeen sustainable development goals. The evaluation showed There is a great deal of compatibility between the two frameworks, in addition to the coincidence of their time horizon, as they both envision a time horizon that extends until 2030. On the other hand, work is underway diligently to align the sustainable development goals with the Kingdom's conditions on the ground, and it is expected to achieve more Harmonization and integration with the integration of sustainable development goals and indicators into the government's action plans and detailed programs that are being prepared and refined within the framework of the Kingdom's Vision 2030. There is no doubt that the sustainable development goals have contributed significantly to this framework through clear recognition of the close interrelationship between the economic, social and environmental dimensions. for development, which is a characteristic that accompanies the concept of sustainability.

The main challenges included in the review are providing data, enhancing the capabilities of statistical agencies to collect and publish statistics related to sustainable development goals, coordinating more effectively between governmental and non-governmental institutions to ensure synergy and non-duplication of efforts, building on existing institutional frameworks without creating new structural structures, and strengthening Sustainable development goals at the local level, and the Kingdom is committed to striving to implement the global development agenda through close cooperation between concerned parties. Activities related to the Sustainable

Development Goals will go closely hand in hand with the implementation of Vision 2030, which is progressing at a steady pace and with great momentum. The main priority areas include improving the quality of indicators of sustainable development goals and the scope of their coverage, analyzing data, continuously aligning government programs and strategies with sustainable development goals, objectives and indicators, preparing strategies to enhance cooperation and collaboration between various actors and parties, and enhancing the role of sustainable development goals at the level Locally, enhancing infrastructure support for the monitoring and evaluation process for the purpose of following up on progress made towards achieving the Sustainable Development Goals at the national and international levels and strengthening international partnerships on the Sustainable Development Goals through development assistance, especially at the regional level.

This review concludes with several lessons learned in the first phase of harmonizing and adapting the sustainable development goals in line with Vision 2030. The most important of these lessons is considering the facts and priorities of the national reality, as relying on the national context in determining sustainable development priorities is possible to prepare, Implementation, and long-term sustainability of results. In addition, it is necessary to clarify the long-term vision and policy consistency in a way that ensures building on existing plans, frameworks and initiatives that aim to achieve the sustainable development goals, and early cooperation with new policies and initiatives through mechanisms that ensure compatibility with the sustainable development goals. It is worth noting the importance of economic diversification as one of the priority aspects of sustainability, as economic diversification is considered a platform to support the inclusion and implementation of sustainable development goals in an effective and applicable manner. In addition, measuring performance in the public sector is extremely important given the Kingdom's

commitment to enhancing the ability of public institutions to measure performance and track progress (General Expert for Measurements, 2023)

There are three methods of water treatments used in KAEC station, UV-Light, Chemical dosing, and Membrane Technology. UV (ultraviolet) light is employed to disinfect water by inactivating or destroying microorganisms like bacteria, viruses, and protozoa. The UV-C wavelength, specifically around 254 nanometers, is highly effective in disrupting the DNA and RNA of these microorganisms, rendering them unable to reproduce and cause harm. In water treatment, UV light is often applied in specialized reactors where water passes through and is exposed to the UV rays. This method doesn't introduce any chemicals to the water, making it a clean and environmentally friendly way to ensure water safety. It's particularly useful in eliminating chlorine-resistant pathogens, providing an additional layer of protection in drinking water and wastewater treatment. On the other hand, while UV light is powerful in disinfection, it doesn't remove physical impurities or contaminants, so it's often used in conjunction with other water treatment processes for comprehensive purification.

Chemical dosing in water treatment involves the controlled addition of specific chemicals to optimize various processes. These chemicals serve different purposes, such as disinfection, coagulation, flocculation, pH adjustment, and corrosion control. Disinfection: Chemicals like chlorine or chlorine-based compounds are added to kill or inactivate harmful microorganisms in water, ensuring it is safe for consumption. Coagulation and Flocculation: Chemicals such as aluminum or iron salts are dosed to destabilize particles in water, allowing them to clump together (coagulation) and form larger particles (flocculation). This aids in their removal during subsequent filtration processes. pH Adjustment: Acids or bases are introduced to control and optimize the pH levels of water. Maintaining the right pH is crucial for the effectiveness of

disinfection and the overall stability of water treatment processes. Corrosion Control: Chemicals like phosphates are used to inhibit corrosion in pipes and plumbing systems. This helps prevent the leaching of metals into the water, maintaining its quality and safety. Chemical dosing is a versatile and essential aspect of water treatment, allowing for the customization of treatment processes based on the specific characteristics of the water source. It plays a key role in ensuring that water not only meets regulatory standards but also remains safe and suitable for various applications.

Membrane technology is a crucial component of advanced water treatment processes, offering efficient separation and purification. Here's a brief summary of using membranes in water treatment:

1. Filtration and Separation: Microfiltration (MF) and Ultrafiltration (UF): These membranes have fine pores that effectively remove suspended particles, bacteria, and some viruses from water.

Nanofiltration (NF): Targets smaller particles, organic molecules, and divalent ions, providing a higher level of purification compared to MF and UF.

2. Reverse Osmosis (RO): RO membranes are highly effective in removing dissolved salts, minerals, and contaminants from water by applying pressure to force water molecules through a semi-permeable membrane. This process is widely used for desalination and producing high-quality drinking water.

3. Membrane Bioreactors (MBR): MBR combines biological treatment (using microorganisms) with membrane filtration, offering enhanced removal of organic pollutants and pathogens. It's commonly used in wastewater treatment.

4. Gas Separation: Membranes are also employed to separate gases, such as oxygen and nitrogen, from air or for capturing carbon dioxide in gas streams.

Benefits: Membrane processes require less space compared to traditional treatment methods.

They are energy-efficient, especially in comparison to methods like distillation for desalination.

Membrane technology provides a physical barrier, minimizing the need for chemicals in some cases.

Challenges:

Fouling: Membranes can get clogged or fouled over time, reducing efficiency. Regular maintenance and cleaning are essential.

Initial costs: The installation of membrane systems can have higher upfront costs, although operational savings may offset this over time.

In conclusion, membrane technology plays a vital role in water treatment by providing selective barriers for filtration and separation processes, contributing to the production of safe drinking water and the treatment of various types of water sources, including wastewater.

Conclusion

In conclusion, Haramain High Speed Train project treated wastewater reuse drive gives enormous volumes of treated wastewater to clients for utilizes including horticultural, modern, business, and region cooling utilizes among other non-consumable purposes and has made a harmless to the ecosystem and monetarily supportable long-haul market for treated sewage emanating. TSE benefits include tending to the water deficiency challenges in KSA and rationing scant water assets, growing new framework, and working it productively and providing ecological advantages like net carbon decreases, by in a roundabout way adding to lesser capital necessities for power and water age.

Haramain High Speed Train project is advancing towards accomplishing its wastewater assortment and treatment framework inclusion targets and treated wastewater use objective. This will deliver water supplies through the normal favorable to cesses of the spring to use in modern and metropolitan sup-handles, and secure key stores for crisis utilizes. Hence, new rules ought to be brought into the treated wastewater rules for groundwater spring re-energize and modern purposes. Further review is recompackted to distinguish the ideal treatment innovation for wastewater in the nation and to assess and relieve the likely effects of treated wastewater impurities on human wellbeing. The proportions of the Saudi government for the turn of events and execution of the waste-water area and the presentation of private-area standard titivation were a powerful move toward further developing wastewater arrangement. However, successful private sector participation necessitates a robust public sector counterpart. Subsequently, further consideration ought to be given to reinforcing public-area capacities for the drawn-out manageability of private-area interest. Besides, the public area needs thorough human limit constructing, guideline, institutional change, and the improvement of an exhaustive treated wastewater data set. This multitude of measures will improve the worth of treated wastewater use and private-area support in wastewater arrangement.

Recommendations

Improve water quality by reducing pollution, eliminating dumping, and minimizing the release of hazardous chemicals and materials in the Haramain High Speed Train Project. Also, by utilizing recycled water in different areas such as irrigation systems, toilet flushing, and washing streets we can achieve a high operational efficiency level and have a good impact on the environment.

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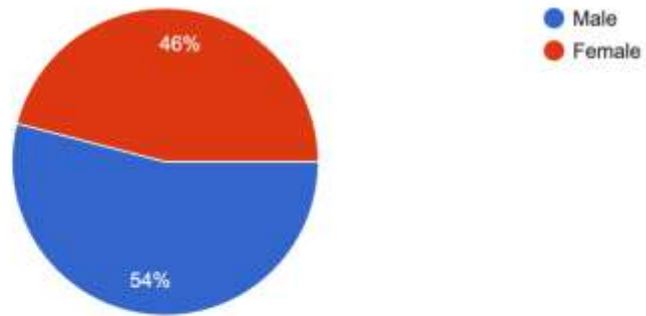
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Appendix

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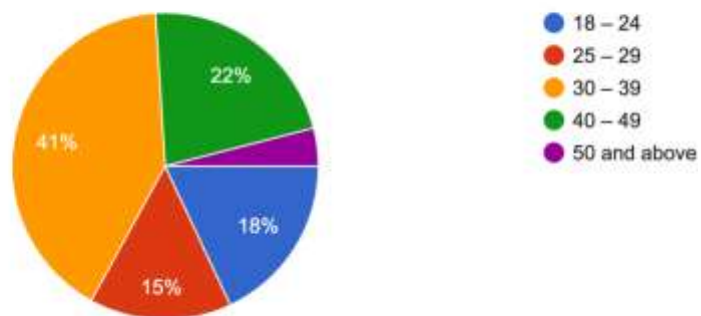
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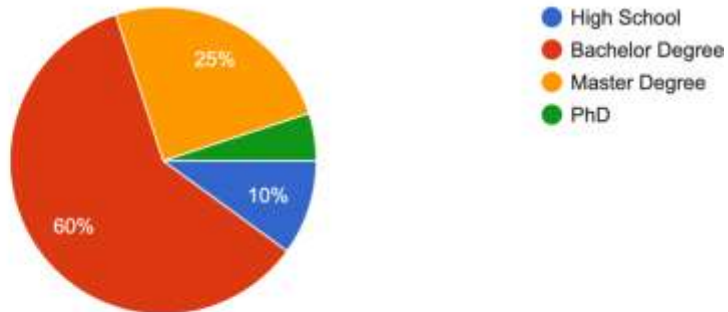


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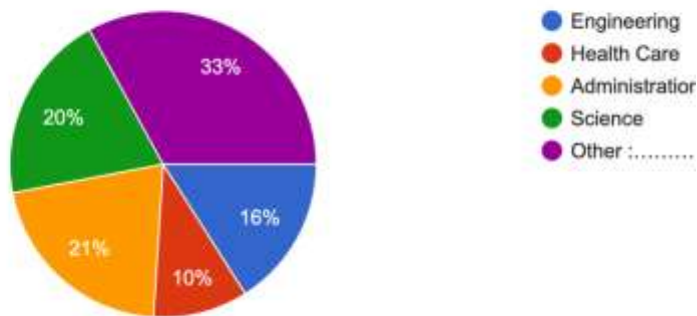
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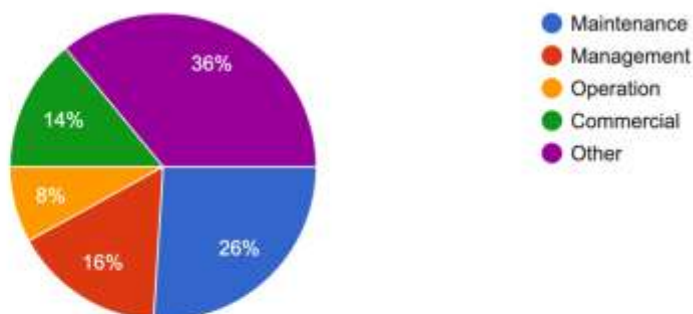
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Major:
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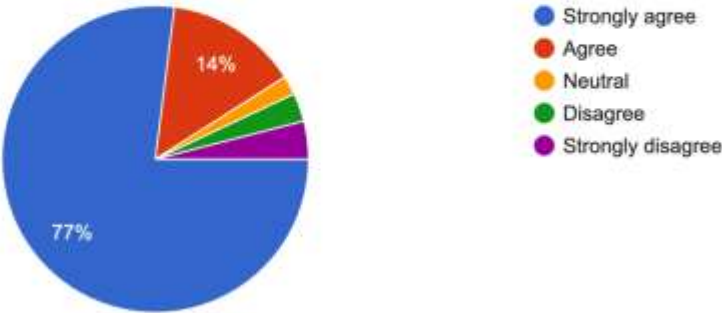


Working Field:
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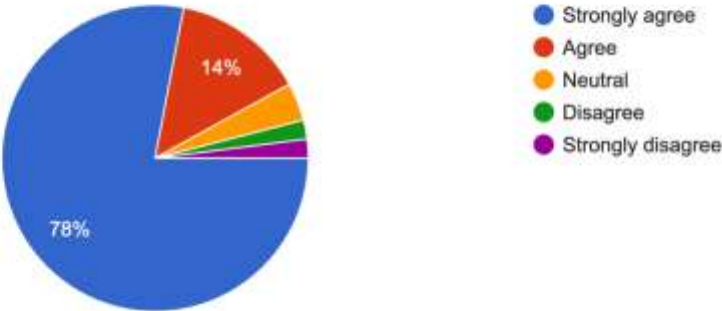
The Impact of Water Recycling on the Operational and Environmental Performance of Facilities
Recycled water is a viable solution for conserving freshwater resources:

100 responses



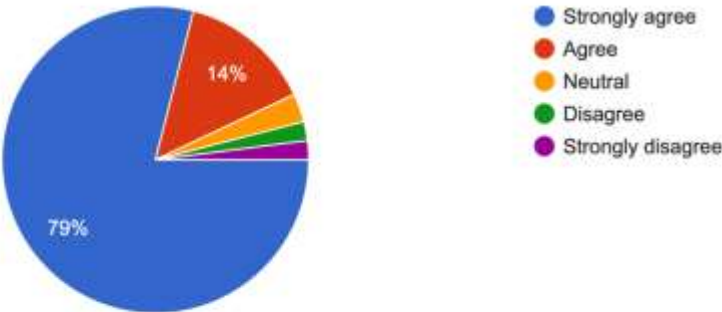
2. Using recycled water for toilet flushing can help reduce overall water consumption

100 responses



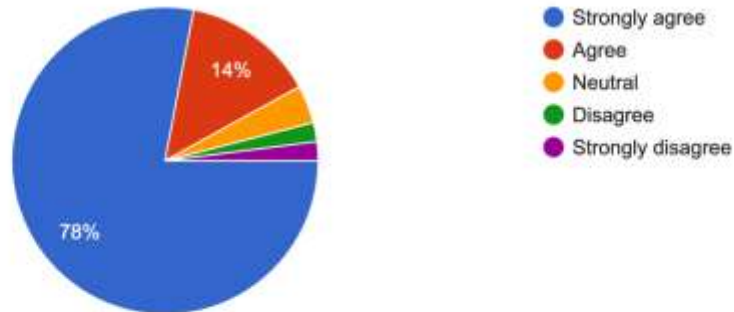
3. Recycled water is safe and poses no health risks when used for toilet flushing

100 responses



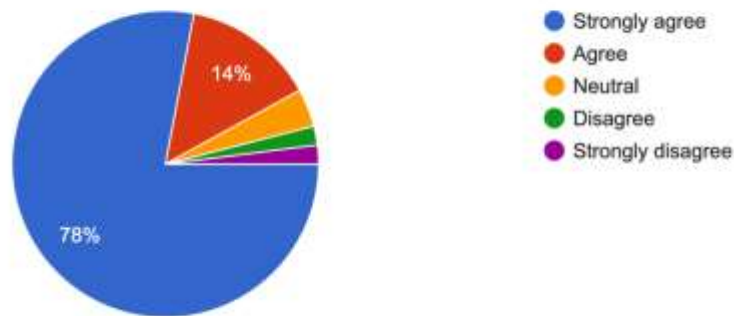
4. The use of recycled water for irrigation in landscapes is an effective way to conserve water

100 responses



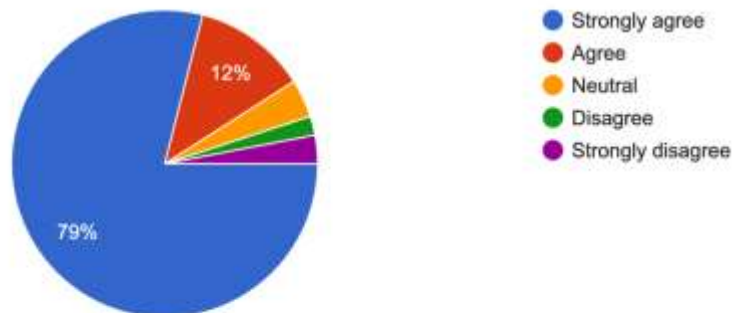
5. Recycled water is suitable for maintaining the health and vitality of plants in landscapes

100 responses



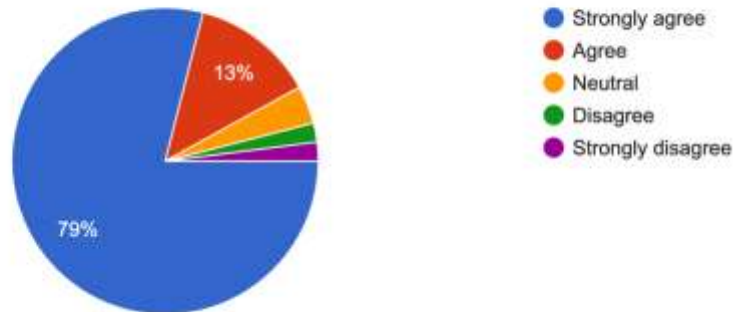
6. The use of recycled water for street washing can help reduce the demand for freshwater sources:

100 responses



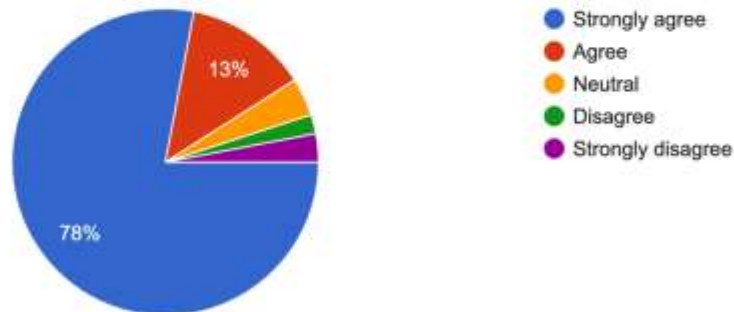
7. Recycled water is a cost-effective alternative to using freshwater for street washing

100 responses



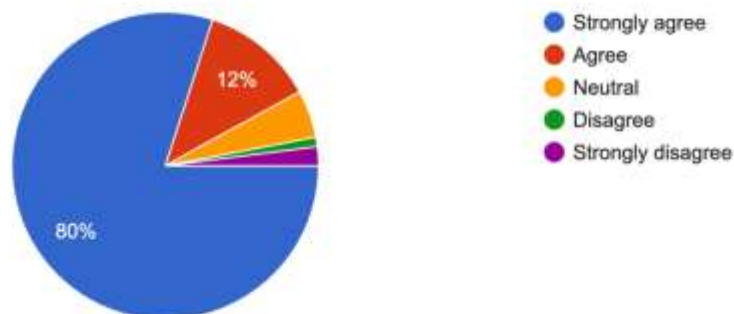
8. The implementation of recycled water systems for toilet flushing, irrigation, and street washing can contribute to sustainable water management practices:

100 responses



9. Public awareness and education about the benefits and safety of recycled water are essential for its widespread acceptance:

100 responses



10. Government incentives and policies should be implemented to encourage the use of recycled water for toilet flushing, irrigation, and street washing:

100 responses

