

*Afr. J. Food Agric. Nutr. Dev.* 2025; 25(5): 26704-26726 <https://doi.org/10.18697/ajfand.142.25315>

Date	Submitted	Accepted	Published
	31 <sup>st</sup> July 2024	8 <sup>th</sup> April 2025	7 <sup>th</sup> July 2025

## RECLAMATION OF DESERT WITH REGULAR APPLICATION OF WASTE WATER IN A SIMULATED PILOT PLOT IN KATHMANDU, NEPAL

Pandey RR<sup>1\*</sup>, Al-Odaini AA<sup>1</sup>, Giri OP<sup>2</sup>, Poddar S<sup>1</sup> and A Bhaumik<sup>1</sup>



**Rajan Raj Pandey**

\*Corresponding author email: [pandeynepal@yahoo.com](mailto:pandeynepal@yahoo.com)

<sup>1</sup>Lincoln University College, Petaling Jaya, Malaysia

<sup>2</sup>School of Engineering, Pokhara University, Pokhara-30, Kaski, Nepal



## ABSTRACT

A desert is a dry, barren area with scarce vegetation and little rainfall, making survival difficult for plants and animals. Desertification is a pressing global issue, especially in African countries where it exacerbates food shortages and hunger. The continuous expansion of desert areas poses significant environmental and socioeconomic challenges. Concurrently, many regions suffer from inadequate wastewater management, leading to outbreaks of waterborne diseases. Addressing these interconnected problems of desertification, improper wastewater management, and hunger demands innovative and sustainable solutions. This study investigated the potential of using wastewater for desert reclamation, aiming to offer a dual benefit: effective wastewater treatment and desert land restoration. A four-month experimental study was conducted to assess the feasibility of using untreated wastewater to reclaim desert lands. The research involved the systematic application of wastewater to designated test plots in desert environments, measuring nutrients Nitrogen, Phosphorous and Potassium (N, P, K) content, carbon content, clay content and silt content. The wastewater contained clay, silt and organic matter. The study revealed that continuous application of wastewater increases essential soil nutrients (N and P), except potassium (K). The initially alkaline wastewater acidifies with time (lowers pH), benefiting plant growth. The results of the study were promising as the nitrogen content increased by 18200 % in four months, the phosphorus by 3583 %, organic matter by 1667 %, total organic carbon by 1643 %, clay by 113 % and silt by 48 %. Moreover, the use of wastewater provided an affordable and sustainable method for managing wastewater, reducing the risks associated with untreated wastewater discharge, such as the spread of waterborne diseases. The limitation of the research was that it was simulated, in Kathmandu and COVID-19 limited the research time to 120 days only. The hot day temperature and no-rain condition was maintained in the experiment enclosure with light bulbs and a plastics roofing material respectively. The reclaimed land showed potential for agricultural use, thereby contributing to local food security and offering a viable solution to hunger in desert communities. These findings suggest wastewater could play a crucial role in desert reclamation. This approach offers a cost-effective, sustainable solution with multifaceted benefits, including environmental restoration, public health improvement and economic opportunities for local communities.

**Key words:** Desertification, Wastewater management, Desert reclamation, Sustainable agriculture, Environmental restoration, Hunger

**Citation:** Pandey RR, Al-Odaini AA, Giri OM, Poddar S and A Bhaumik  
Reclamation of desert with regular application of waste water in a simulated pilot plot in Kathmandu, Nepal. *Afr. J. Food Agric. Nutr. Dev.* 2025; **25(5)**: 26704-26726 <https://doi.org/10.18697/ajfand.142.25315>



## INTRODUCTION

The scarcity of water resources and growing desertification threaten sustainable development in arid regions like the Middle East, North Africa and deserts in China and Mongolia. Limited fresh water and expanding deserts degrade valuable land and ecosystems, posing significant environmental challenges globally [1]. These pressing issues necessitate innovative approaches to water management and desert reclamation [2]. Deserts, with high temperatures, low humidity, and scarce water, create extreme conditions that severely affect plant growth and survival [3]. Sparse desert vegetation results from water scarcity, due to high evaporation, unstable sandy soil, temperature extremes, resource competition and specific plant adaptations [3].

Treating and applying wastewater can combat water scarcity and desertification. Often discarded untreated wastewater from domestic, industrial and agricultural sources leads to pollution and wastes valuable resources [4]. Properly treated, wastewater can enhance moisture in deserts and restore ecosystems in arid regions, supporting sustainable agriculture and mitigating desertification. In the Middle East and North Africa (MENA), where water scarcity and desertification are pressing issues, exploring the feasibility and effectiveness of natural wastewater treatment for desert reclamation is crucial [5].

The Gulf Cooperation Council (GCC) countries Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates (UAE) face severe water shortages threatening sustainable development and constraining human, industrial and agricultural growth. Rapid urbanization and rising living standards have exacerbated this issue [6]. Despite arable land being just 4.3 % of the GCC's total area, agriculture consumes 70 % of renewable water resources, with even higher usage in Saudi Arabia, the UAE and Oman [7, 8]. Surprisingly, agriculture contributes just 0.8 % to the Gross Domestic Product (GDP) in GCC countries [9]. Researching a test plot simulating desert-like conditions can provide insights into the benefits, challenges and environmental impacts of using untreated wastewater for reclamation. Deserts form through complex, multifaceted processes influenced by various factors, with unique characteristics and formation mechanisms varying across different deserts globally.

In a typical Xinjiang oasis, Chinese scientists systematically examined agricultural reclamation, summarizing farmers' experiences, identifying challenges, and proposing solutions. Oasis agriculture faces water scarcity, ecological fragility, low soil fertility and soil salinization. Addressing these issues requires water conservancy projects and improved transport systems to access water resources



[10]. Land consolidation and intensive management enhance oasis agriculture. Advanced irrigation and fertilization techniques boost productivity, while tailored approaches for soil salinization, including soil amendments, biological treatments, and subsurface salt drainage, are essential [11].

The western desert of Egypt covers a significant area, necessitating prioritization in sustainable development projects. About 420,000 hectares consist of sandy and calcareous soils with low organic matter and nitrogen content, as revealed by soil analyses [12]. Alluvial soils in Egypt, including clayey and loamy clay types, show moderate available phosphorus levels by Olsen's method and high soluble and exchangeable potassium levels, typical of most Egyptian alluvial soils [13]. In arid ecosystems, contaminant attenuation occurs through physical filtration, soil sorption, biodegradation and plant uptake. Vegetation absorbs and soil adsorbs nutrients, preventing contaminants from reaching groundwater. This system offers cost-effective benefits such as soil restoration, vegetation recovery and water reuse. However, desert soil faces challenges such as high infiltration rates, low organic matter, coarse texture and limited water and fertilizer retention, making it less suitable as a sink for wastewater contaminants [3].

Chile's recent mega-drought highlights the urgent need for alternative irrigation water sources. Although, nearly 100% of urban areas have wastewater treatment coverage, direct reuse remains under 1% due to regulatory gaps and limited frameworks. To enhance recycled wastewater use for irrigation, it is crucial to update institutional and legal frameworks, engage rural communities and study emerging contaminants [14]. In arid regions, reusing wastewater enhances economic efficiency and environmental conservation in water-intensive activities. Gradually substituting wastewater for groundwater can achieve these goals. While some commercial crops can use untreated wastewater, dilution and advanced treatment are needed for other uses to meet water quality standards [8]. In Tucson and Phoenix, Arizona, municipal wastewater is used for irrigating various crops, landscape irrigation, replenishing recreational lakes, and mitigating the environmental risks of wastewater disposal [15].

Increasing population pressure is reducing available farmland, necessitating the development of low-cost technologies that maintain the natural resource balance without further degrading the environment [16]. This research investigated desert reclamation through the continuous application of untreated wastewater, focusing on soil quality and ecosystem impacts in a simulated desert environment. Wastewater treatment, a secondary aim, naturally results from reclamation. The findings are crucial for water resource management, land restoration and sustainability in arid



regions, contributing to sustainable water use and combating desertification. The proposed research in Kathmandu, Nepal, focused on using raw wastewater for desert reclamation. A test plot simulating desert-like conditions was used to assess wastewater treatment effects on soil quality exploring the potential for land restoration in arid regions.

### Research Questions

1. What are the impacts, in terms of nutrients and other soil constituents, of continuous wastewater application on a test plot simulating a desert?
2. Would the sand aggregate while continuously applying municipal wastewater to the test plot of the sand bed?

### MATERIALS AND METHODS

The researchers aimed to replicate desert-like conditions at the Bagmati Sewerage Treatment Plant in Kathmandu, Nepal. A continuous wastewater supply was essential, so the research plot was chosen next to the plant's inlet portion near the international airport, ensuring consistent access to raw wastewater for the experimental setup.

### Simulation of Desert-like Conditions

A desert is a barren, arid region with limited vegetation and minimal precipitation, making it challenging for plants and animals to thrive. Deserts experience extreme temperature variations, with hot days and cool nights. They are classified based on characteristics and location, such as hot deserts, cold deserts, coastal deserts and polar deserts. This research focused on hot deserts, specifically the Sahara Desert in Africa and the Arabian Desert in the Middle East. These regions experience high daytime temperatures, often exceeding 100°F (38°C), and have sparse vegetation, with sandy or rocky terrain. To replicate these conditions, the experimental setup in Kathmandu at the Bagmati Sewerage Treatment Plant included simulating aridity due to high temperatures, a loose sandy bed, and no surface vegetation. The research plot, located next to the treatment plant's inlet, ensures a continuous supply of raw wastewater. This setup helped assess the potential for using untreated wastewater in desert reclamation by examining its effects on soil quality and ecosystem dynamics.

### Waste Water Treatment Techniques and Process

A comprehensive overview of various aspects of wastewater treatment by land application, including techniques for applying wastewater and mechanisms for removing pollutants is explained thoroughly by Gohil [17]. The main treatment parameters for wastewater are Biochemical Oxygen Demand (BOD), Total



Suspended Solids (TSS), and Nitrogen (N). Wastewater was applied to the sand bed of the test plot in this research for natural treatment through percolation. Over time, the wastewater did seep into the sub-surface, with suspended organic matter retained by the sand and transforming into a humus-like substance. This humus material benefits soil by supporting microorganisms that break down organic matter into inorganic forms, readily absorbed by plant roots. Additionally, the suspended inorganic substances, mainly silt and clay, in the wastewater would be retained in the sand and build up. The high daytime temperatures created by hanging 10 numbers of 200 W incandescent electric bulbs in the test plot, simulating hot desert conditions, would cause some wastewater to evaporate. Nutrients such as nitrogen, phosphorus and potassium (N, P, K) would partially remain in the sand, enriching it and making it more conducive to vegetation growth over time. This approach aimed at transforming the sand bed into fertile soil, suitable for supporting plant life and aiding in desert reclamation efforts.

The wastewater that was applied was tested in the laboratory of the Treatment Plant daily and the authorities availed the records. The parameters measured were: pH, Bio-Chemical Oxygen Demand (BOD<sub>5</sub>), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Ammonical Nitrogen or Kjeldahl Nitrogen (NH<sub>3</sub>- N), and Oil and Gas (O and G). BOD<sub>5</sub> was useful to see the variation in organic matter, pH values were compared to see increase/ decrease with time, TSS was useful to compare the variation in clay and silt, and NH<sub>3</sub>- N was useful to see if nutrient level increased to support plant growth during data analysis.

### **Experimental Set-Up**

As shown in Figures 1 and 2 a one-square-meter pit was excavated (Length = 1 m, Breadth = 1 m, Depth = 0.27 m) near the inlet of the wastewater treatment plant, surrounded by a single brick cemented wall on all four sides.





**Figure 1: The test model with all the bulbs lit**

This area was chosen to represent a desert landscape, cleared of debris and vegetation to prevent interference with the experiment. The test pit had dimensions Length (L= 1.09 m) × Breadth (B= 1.09 m) × Depth (D= 0.27 m), resulting in a volume of 0.322 cubic meters (322 liters). A brick masonry wall was constructed around the pit with a depth of 0.27 m, providing a volume of 0.27 cubic meters (270 liters). The sand was filled up to the fourth bricklayer, leaving one layer as a freeboard- aiming to fill with wastewater during the experiment. The sand bed was leveled to ensure a consistent surface. A sand sample was collected in a plastic bottle and sent to a laboratory for analysis of its composition, including nitrogen (N), phosphorous (P), potassium (K), organic matter, total organic carbon (TOC), clay and silt, to compare with the changes during the research. A roofing cover made of an iron frame (L = 1.5 m, B = 1.5 m, and H = 2.0 m) with 50-micron thick plastic sheets covered the top and half the sides to prevent rainfall as a part of the desert- simulation. The lower open portion was fenced with chicken wire mesh to protect the test site from animals. Ten numbers of 200-watt incandescent filament electric bulbs were hung from the frame at a height of 30 cm from the sand surface to increase the local ambient temperature simulating the desert heat. The temperature in the test pit varied from 45°C to 55°C in the daytime, mimicking the thermal conditions of deserts in India, the Middle East and North Africa. The bulbs were turned off during nighttime to simulate the night conditions of the desert.



**Figure 2: Application of wastewater and ambient temperature measurement**

This setup maintained a controlled environment for the experiment. Photographs of the setup and the application of wastewater, along with ambient temperature measurements, were documented for reference. The test pit was designed to allow raw wastewater to percolate through the sand bed, where suspended organic matter would be retained and transformed into humus, enhancing soil fertility. Inorganic substances such as silt and clay, theoretically, would also be retained, gradually building up in the sand.

### **Application of Waste Water**

An electric motor used to pump wastewater had a rated discharge capacity of 10,000 liters per hour. The time was measured, and the volume applied varied based on plot size, application rate, and the sand bed's absorption capacity. Apple wristwatch was used to measure time and the motor's rated capacity was used for getting the discharge of the motor and the volume was calculated based on these two data. On average, it took 1 minute and 21 seconds to fill the test plot, with a maximum time of 1 minute and 30 seconds and a minimum of 1 minute and 10 seconds. The average volume of wastewater applied daily was 222 liters. The motor, connected to a plastic pipe, evenly distributed the wastewater over the test plot daily, ensuring consistent and uniform application to maintain the experiment's reliability. A statistical Significance test was conducted to check the reliability of collected data from the wastewater and sand bed.

### **Data Collection**

Two types of data were collected as follows:



**Initial Characteristics of Wastewater:** The main parameters that were measured in laboratory for 4 months are shown, as an example, in Table 1.

The wastewater parameters (BOD<sub>5</sub>, TSS, NH<sub>3</sub>-N, etcetera) measured in the lab were compared with the results obtained after analysis of the sand bed to see whether the organic matter, Clay, and Silt and Nitrogen contents were in line with corresponding the input parameters. Statistical Significance was checked for BOD<sub>5</sub> of wastewater versus Organic matter of sand bed, TSS of wastewater versus both clay and silt of sand bed, and NH<sub>3</sub>- N of wastewater versus N content of sand bed.

**Measurement of Changes in Composition of Sand:** Monthly (June 20, July 20, August 20, and September 20 of the year 2023) samples of sand from the test plot were collected in half-liter plastic jars and analyzed for N, P, K, organic matter, TOC, silt and clay to compare with the original sample and find out the changes in the composition and characteristics of the sand media with the application of wastewater. The parameters analyzed by the International Organization for Standardization (ISO) certified laboratory for sand samples were: pH, temperature, sodium chloride (NaCl) content, total nitrogen, total phosphorus, potassium, organic matter, total organic carbon, clay and silt contents. The obtained test data from the laboratory were tabulated and bar charts were worked out for the changes in concentrations of these parameters in MS Excel sheets. The changes over time (each month) were compared to the previous records.

The different parameters were measured in the lab following the below-mentioned methods: pH by 4500 H<sup>+</sup> B, APHA 23<sup>rd</sup> Edition, temperature by 2550 B, APHA, 23<sup>rd</sup> Edition, NaCl by 3500- Na B, APHA 23<sup>rd</sup> Edition by calculation, total nitrogen by 4500 N<sub>org</sub> B, APHA 23<sup>rd</sup> Edition, total phosphorus by 4500- P E APHA 23<sup>rd</sup> Edition, total potassium by 3500 KB APHA 23<sup>rd</sup> Edition, organic matter by 4500 O D APHA 23<sup>rd</sup> Edition IS 383- 2016, total organic carbon by Walkley- Black /5310 A and 5310 BA PHA 23<sup>rd</sup> Edition comparison, clay by IS 383- 2016, and silt contents by IS 383- 2016.

### **Continuation and Long-Term Monitoring**

- Daily application of wastewater was continued and samples were collected for lab tests over an extended period of 4 consecutive months to understand the trend of changes due to the daily application of wastewater on the sand bed.
- The data obtained from the lab were regularly reviewed and analyzed to monitor changes and validate the conclusions of the study.
- The temperature was measured by using a calibrated thermometer 4 times on the same dates when the sand samples were taken.



## Data Analysis

The study employed **paired t-tests** to compare wastewater parameters ( $\text{NH}_3\text{-N}$ ,  $\text{BOD}_5$ , TSS) with corresponding sand fractions (N, OM, clay and silt). **Pearson correlation** determined the strength of relationships, while **regression analysis** in **MS Excel** sheet identified trends and dependencies.

## Significance Test

The **t-test** was conducted to assess the statistical significance, with a **p-value**  $< 0.05$  indicating meaningful differences between input and output values. High correlation values further validated relationships. Strong correlations and significant p-values confirmed that wastewater characteristics influence sand composition, supporting the reproducibility and accuracy of the study.

## RESULTS AND DISCUSSION

High daytime temperatures ensured some wastewater evaporation, and nutrients such as nitrogen, phosphorus and potassium were partially retained in the sand, enriching it and supporting potential vegetation growth.

### Data Illustration and Explanation

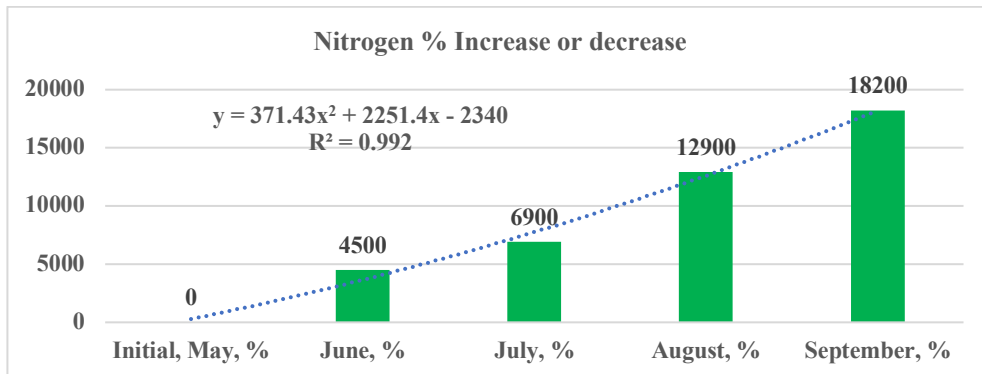
Table 2 presents the laboratory test results of sand media over four months, showing changes in nutrient and particle composition. Nitrogen and phosphorus exhibited significant increases, peaking in the third month before phosphorus declined in the fourth. Potassium fluctuated, with declines in the second and fourth months. Organic matter and total organic carbon (TOC) rose sharply, enhancing soil fertility. Clay and silt contents showed gradual increments, indicating sediment deposition. These trends highlighted the impact of wastewater on soil enrichment and nutrient retention efficiency.

Table 3 presents the incremental percentages of key soil constituents over four months following wastewater application. Nitrogen content showed a steady increase from 0.001% to 0.183%, enhancing soil fertility. Phosphorus initially rose but dropped in September, indicating potential leaching or fixation. Potassium fluctuated, peaking in May and August. Organic matter and total organic carbon increased significantly, with a peak in August, improving soil structure. Clay and silt contents showed minor variations, suggesting gradual sediment deposition.

These trends highlight the impact of wastewater on soil nutrient dynamics, emphasizing the need for controlled application to optimize soil health and prevent nutrient losses.



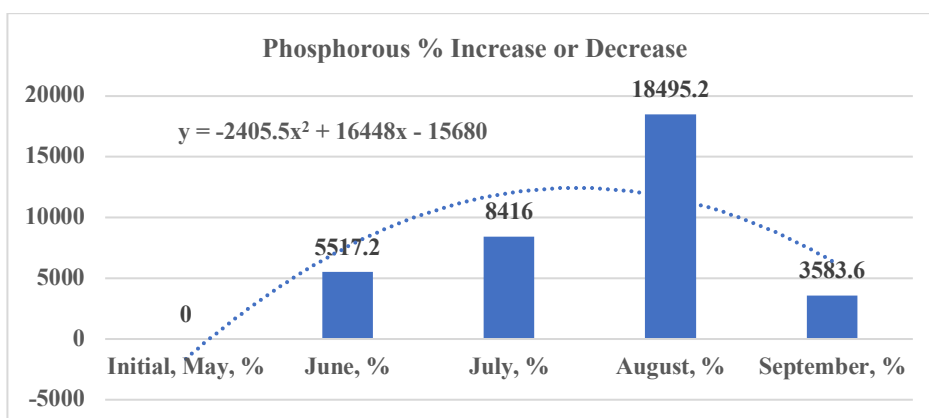
**Nitrogen:** Figure 3 illustrates the percentage increase in nitrogen content over five months, showing a consistent upward trend.



**Figure 3: Changes in the nitrogen content of the sand after regular application of wastewater**

Here,  $R^2 = 0.992$  indicates a strong correlation. Nitrogen levels increased from 4500% in June to 18200% in September, highlighting significant soil enrichment due to wastewater application. The trend suggests exponential nitrogen accumulation, which could enhance soil fertility but may also indicate potential risks of nutrient saturation or leaching over time.

**Phosphorous:** Figure 4 below illustrates the percentage increase in phosphorus over four months, showing an initial rise followed by a decline. Phosphorus increased from 5,517.2% in June to a peak of 18,495.2% in August before dropping to 3,583.6% in September. The sharp decrease in phosphorus (P) levels as shown in the below Figure by the fourth month suggests possible soil saturation, phosphorus fixation, or leaching due to excessive accumulation. Initially, P levels increased rapidly, indicating strong adsorption by soil particles.

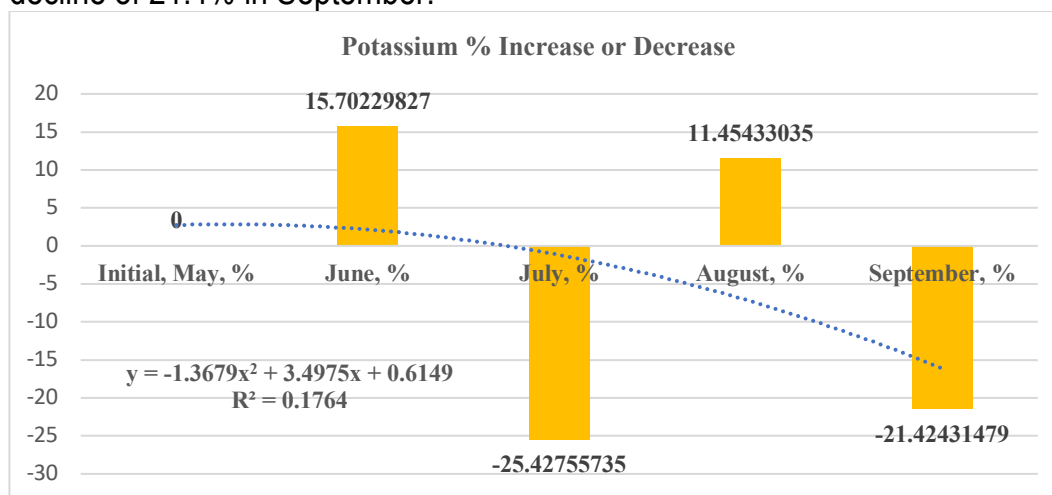


**Figure 4: Changes in the Phosphorus content after regular application of wastewater**

Phosphorus in wastewater is typically found in the form of orthophosphates, polyphosphates and organic phosphates [18]. Orthophosphates, compared to nitrogenous compounds, are highly soluble in water, while polyphosphates can undergo hydrolysis to form orthophosphates, which are also soluble [18]. After four months, the value reaches 3583.6%, significantly higher than the initial 0%, benefiting plant growth by enhancing soil nutrients and improving overall fertility for better agricultural productivity.

The decline in September indicates possible phosphorus fixation, leaching, or reduced soil retention. This trend emphasizes the importance of managing wastewater application to maintain phosphorus availability while preventing excessive accumulation or loss. The decrease in the phosphorous content in the second month may be due to leaching because it was the peak rainy season (the last 11 days of June and the beginning 19 days of July is the peak monsoon period in Nepal). The heavy rainfall in Kathmandu may have led to a dilution in the content of phosphorous in the wastewater and the regular application of dilute wastewater could have leached out the already present potassium in the research plot.

**Potassium:** Figure 5 shows the percentage increase or decrease in potassium over five months. Potassium initially increased by 15.7% in June but dropped significantly by 25.4% in July. A partial recovery occurred in August (11.5%), followed by another decline of 21.4% in September.



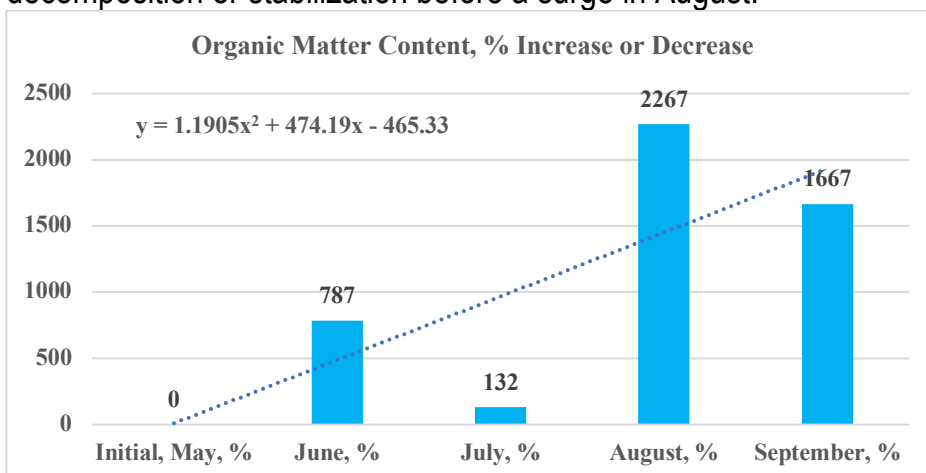
**Figure 5: Changes in the potassium content after regular application of wastewater**

The reason mentioned above is also supported by the statement that potassium is more soluble in water than nitrogenous compounds[18]. Thus, this could be the reason for the depletion of potassium in the applied wastewater as the volume of

wastewater increased in those months because of more rainfall. The monsoon season extended till October in the year 2023 in Kathmandu, Nepal and it could be the reason for the further decrease in Potassium content in the test plot as the wastewater was highly diluted. Further field-level research is necessary to know the exact reason for variable results every next month.

The fluctuations suggest potassium instability, possibly due to leaching, or soil interactions. Proper wastewater management is necessary to maintain balanced potassium levels for optimal soil fertility.

**Organic Matter:** Figure 6 illustrates the percentage increase in organic matter content over five months, showing an overall rising trend. Organic matter increased significantly from 787% in June to 2,267% in August, followed by a slight decline to 1,667% in September. The initial drop in July (132%) may indicate microbial decomposition or stabilization before a surge in August.



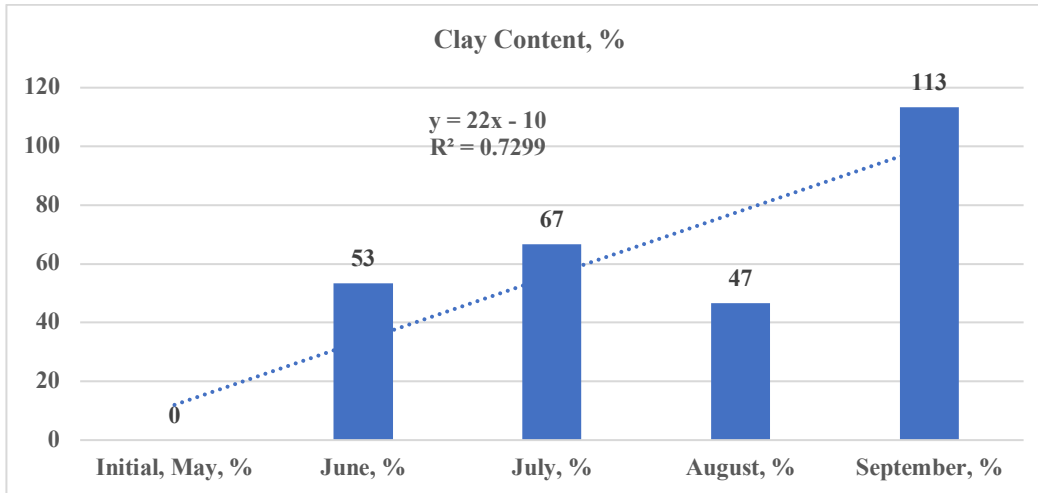
**Figure 6: Changes in the organic matter content after regular application of wastewater**

The trend highlights the effectiveness of wastewater application in enhancing soil organic matter and improving fertility and soil structure.

The source of OM was the wastewater that was applied daily. The influent OM and output OM have been mentioned in Table 4 and the regression analysis done has also proved that the input and output data were consistent.

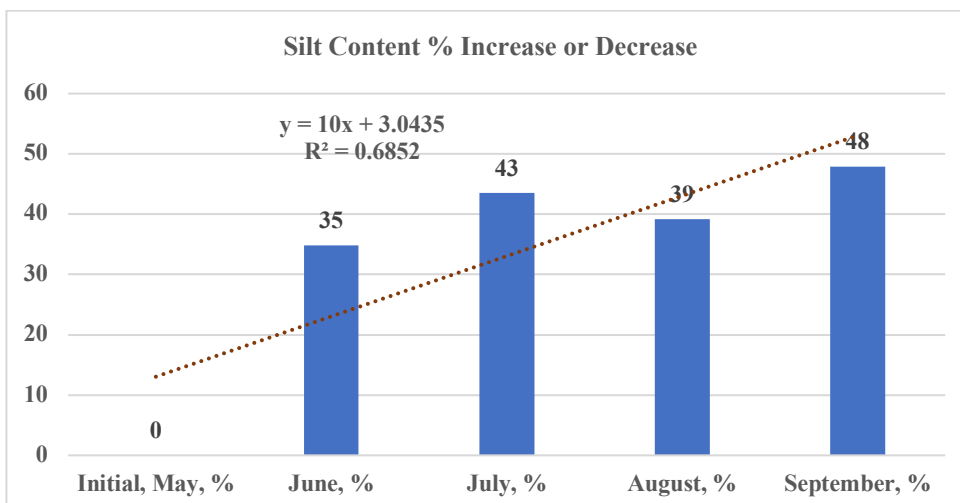
**Clay:** The data in Figure 7 shows the content of clay increased by 53 % with a month of application of wastewater and it further increased to 66.7 % at the end of the second month but, it went down slightly at the end of the third month to 46.7 %. But, again it increased to 113 % at the end of the fourth month. The fraction of clay at the end of the fourth month was 0.032 % as compared to 0.015 % at the beginning of

the research and that is an increment of 113 %, which supports the research hypothesis.



**Figure 7: Changes in the clay content after regular application of wastewater**

**Silt:** As shown in Figure 8, the content of silt increased by 35 % in the first month of application of wastewater and it further went up to 43.5% in the second month but, came down slightly at the end of the third month and again increased to 48 % at the end of the fourth month. The fraction of silt at the end of the fourth month of application of wastewater was 0.034 % as compared to 0.023 % at the beginning of the research and that is an increment of 48 % and the result supports the hypothesis of the research.



**Figure 8: Changes in the silt content after regular application of wastewater**

**Nitrogen:** The initial concentration of nitrogen (N) was a mere value of 0.001 % in the total content of the sand sample tested in the lab. Within 4 months of daily

application of wastewater, the concentration became 0.18% and that is a huge rise of 18200 %. Such a level of increase in the first prime nutrient for plant growth is a very positive sign for the reclamation of sand mass.

**Phosphorus:** The initial concentration of Phosphorus (P) was only 0.00025 Limit to only 2 decimal places % in the total content of the sand sample tested in the lab. Within 4 months of application of waste water daily the concentration became 0.01 % and that is a huge rise of 3583 %. Such a level of increase in the second prime nutrient for plant growth is a very positive sign for the reclamation of sand mass.

**Potassium:** The initial concentration of Potassium (K) was 0.46 % Be consistent in the use of the number of decimal places in the total content of the sand sample tested in the lab. Within 4 months of daily application of wastewater, the concentration became 0.36 % although it had risen to 0.51 % at the end of the third month. It is a decrease of 21.42 % as compared to the initial value and it could be because of prolonged monsoon diluting the wastewater of Kathmandu.

**Organic Matter:** The initial concentration of organic matter was just 0.06 % in the total content of the sand sample tested in the lab. Within 4 months of daily application of wastewater, the concentration became 1.06 %, a rise of 1667 % although it had reached 1.42 % in the third month which was a rise of 2266.67 %. Such a huge level of increase in organic matter is a very positive sign for the reclamation of sand mass as the cohesive property of the sand will increase and it will be able to hold the roots of plants. The equation obtained for the best-fit curve of the bar chart was  $y = 0.288x - 0.2242$ , where y is the percentage of organic matter in the sand bed and x is the number of months of application of wastewater. The minimum percentage of Organic matter for sand to become sandy soil is less than 0.5 % as already mentioned. So, the organic matter content of the sand rose from 0.01 % to 0.64 % in just 3 months, and in 4 months it had reached 0.93 % and it would keep on increasing with further addition of wastewater daily. Therefore, Organic matter is more than enough for reclamation of the sand bed.

**Clay:** The initial content of Clay was only 0.015 % of the total content of the sand sample tested in the lab. Within 4 months of daily application of wastewater, the concentration became 0.03 % which is an increase of 113.33 %. Such an increase in clay content is a positive sign for the reclamation of sand as the clay promotes cohesive properties as well as binding properties of the sand will increase and it will be able to hold the roots of plants. The equation obtained for the best-fit curve of the bar chart was:  $y = 0.0033x + 0.0135$  where y is the percentage of clay in the sand bed and x is the number of months of application of wastewater. The minimum



percentage of clay content in sand for it to convert to a sandy soil should be less than 5 % as already mentioned. The clay content of the sand increased from 0.01 % to 0.03 % in 4 months and it would keep on increasing with further addition of wastewater daily. It is estimated that it would take 298 months of continuous application of wastewater for the clay content to increase to 1% in the sand. A high rate of flow and thus the volume of daily application of wastewater shall shorten the period of reclamation.

**Silt:** The initial content of silt was 0.02 % in the total content of the sand sample tested in the lab. Within 4 months of daily application of wastewater, the concentration became 0.03 % , a rise of 47.83 %. Such a level of increase in silt content is a positive sign for the reclamation of sand mass as the cohesive as well as binding properties of the sand will increase and it will be able to hold the roots of plants. The equation obtained for the best-fit curve of the bar chart was  $y = 0.0023x + 0.0237$ , where y is the percentage of clay in the sand bed and x is the number of months of application of wastewater. Anything above 1 % of silt in the sand is good enough for it to sand. A continuous application of wastewater will keep on increasing the silt content of the sandy soil. The rate of application of wastewater during the experiment was just around 2 minutes a day. A continuous application for 424 months is needed to reach 1% silt concentration at the given flow rate. Increasing the flow rate and wastewater volume will accelerate the process, reducing the reclamation period significantly by enhancing sediment deposition efficiency.

**pH:** The initial pH of the sand sample was 7.8 and it decreased each month gradually to 7.2, 7.0, 6.9 and finally to 6.7 at the end of the fourth month. Neutral or slightly acidic soil is good for plant growth and thus, such a decrease in pH is desirable.

Soil physicochemical indicators such as texture, pH, nutrients and organic matter are vital for assessing soil quality, yet they are rarely evaluated in tropical regions [19]. Sandy soil primarily consists of sand particles (0.05 mm to 2.0 mm), making up 70 % to 90 % of the soil. It has low organic matter content (0.5 % to 3 %), affecting fertility and water-holding capacity [14]. The water-holding capacity of sandy soil ranges from 5 % to 20 % when saturated, due to large pore spaces that ensure good drainage and aeration, with air-filled porosity from 30 % to 50 %. Silt and clay contents are minimal, with silt ranging from 1 % to 10 % and clay typically under 5 % [14].

Previous research on desert reclamation has explored treated wastewater for land restoration but not untreated wastewater. This study aimed to address regional variations, optimize treatment processes, and develop tailored approaches for diverse desert environments globally [16]. Desert soil, 90-95 % sandy in low-rainfall



regions, is infertile due to low nitrogen and negligible organic matter, despite being rich in calcium carbonate and phosphate. Providing nitrogen as nitrates from fertilizer and ensuring proper irrigation could support crops such as barley, rape, cotton, wheat, millets, maize and pulses [19]. The Taklimakan Desert Highway Shelterbelt (TDHS) project showcases the successful human-assisted establishment of vegetation on hyper-arid mobile dunes, supported solely by local saline groundwater. This project illustrates a viable method for promoting plant growth and stabilizing sand dunes in extreme desert conditions, contributing to land restoration and environmental sustainability [20].

### Significance Test

Table 4 presents the aggregated monthly data for **NH<sub>3</sub>-N**, **BOD<sub>5</sub>**, and **TSS** in wastewater, along with corresponding **N**, **organic matter (OM)**, **clay** and **silt fractions** in sand samples. Cumulative values of all the parameters were calculated, and regression analysis was conducted for each variable pair using **MS Excel** to determine statistical significance. The analysis evaluated the relationship between wastewater parameters and sand composition, identifying potential correlations and trends.

For **nitrogen**, the mean ammonia nitrogen (NH<sub>3</sub>-N) concentration in wastewater (3586.77 mg) significantly differed from the nitrogen content in the sand (0.09%) (**p-value = 0.04** for the two-tailed test). A strong **Pearson correlation (0.99)** suggests a direct relationship between input and output nitrogen levels. The **OM** analysis reveals a statistically significant difference (**p-value = 0.02**), with wastewater OM levels averaging **6458.94 mg**, while OM in sand samples averages **0.64%**. The **moderate correlation (0.59)** indicates variability in how OM transfers from wastewater to sand. For **clay**, the input **TSS** from wastewater (**24662.23 mg**) shows a significant difference from the clay content in sand (**0.02%**) (**p-value = 0.04**). A **strong correlation (0.87)** suggests that higher TSS levels contribute to increased clay deposition. Similarly, for **silt**, the difference between wastewater TSS and silt in sand is significant (**p-value = 0.04**), with a **strong correlation (0.88)**. This indicates that wastewater characteristics influence silt deposition. Overall, all parameters exhibit significant differences between input and output values, suggesting that wastewater composition affects sand properties, particularly regarding nitrogen, organic matter, and particulate matter retention. These findings highlight the potential impact of wastewater on sand composition.



## CONCLUSION AND RECOMMENDATIONS FOR DEVELOPMENT

The results of the tests obtained from 120 days of continuous application of wastewater in the test plot of the sand bed have shown an accumulation in all the parameters measured (N by 18200 %, P by 3583 %, organic matter by 1666 %, total organic carbon-TOC by 1642 %, clay content by 113 %, and silt by 47 %), except for potassium (K) and pH. The decrease in pH is highly favorable for plants. The statistical Significance Test shows that the laboratory test results of wastewater before application and corresponding parameters tested in the sand sample were consistent and statistically significant as the p-values for all the parameters were less than 5%.

These results can lead to a significant impact on the reclamation of deserts in the future. Future research should be conducted in actual desert environments, with the findings from this study guiding such field research. Countries located near or within deserts can develop policies to utilize the vital resources present in wastewater to reclaim deserts for the benefit of both humans and the environment. On the other hand, the environmental pollution caused by the mismanagement of wastewater may also be abated by the utilization of wastewater- otherwise disposed of indiscriminately impacting human health.

## ACKNOWLEDGEMENTS

We extend our sincere gratitude to Prof. Dr. Sateesh Kumar Ojha, Regional Dean, Lincoln University College, Malaysia for overall guidance in this research. Similarly, we thank the local guide Associate Prof. Dr. Mahesh Prasad Bhattarai, IOE Pulchowk, Kathmandu, Nepal for his invaluable guidance during the field research.

## Declaration of competing interest

There are no financial or personal conflicts of interest between the authors and any individuals or organizations that could inappropriately influence this work.

## Authors' Contributions

**Rajan Raj Pandey:** Conceptualized the study, developed the methodology, and led the data collection process, data analysis, and initial drafting of the manuscript.

**Remaining Author:** Contributed to the supervision of research work, drafting, and critical revision of the manuscript.

## Funding

This research received no specific grant from public, commercial, or not-for-profit funding agencies.



**Table 1: Daily Representative Characteristics of Applied Raw Sewage Composite Sample**

Date	pH	BOD5 (mg/L)	COD (mg/L)	TSS (mg/L)	NH3-N (mg/L)	O & G (mg/L)
Method	Digital pH meter (Hach)	APHA 5210-B	EPA Method 410.4	APHA 2540 D	EPA Method 350.1	APHA 5520 B
05/21/23	6.96	389.4	818	415	62.7	63
05/22/23	6.87	374	1119	395	34.7	78

Source: Bagmati Sewerage Project Daily Records

**Table 2: Test results of the sand media**

Parameters	Initial, %	1Month, %	% Increase	2 Month, %	% Increase	3 month, %	% Increase	4 month, %	% increase
Nitrogen	0.001	0.046	4500.00	0.070	6900.00	0.130	12900.0	0.183	18200.00
Phosphorous	0.00025	0.014	5517.20	0.021	8416.00	0.046	18495.2	0.009	3583.60
Potassium	0.456	0.528	15.70	0.340	-25.43	0.509	11.45	0.359	-21.42
Organic Matter	0.060	0.532	786.67	0.139	131.67	1.420	2266.67	1.060	1666.67
TOC	0.035	0.310	785.71	0.081	131.43	0.820	2242.86	0.610	1642.86
Clay	0.015	0.023	53.33	0.025	66.67	0.022	46.67	0.032	113.33
Silt	0.023	0.031	34.78	0.033	43.48	0.032	39.13	0.034	47.83

**Table 3: Increment Percentage of each constituent**

S. N.	Initial, May, %	June, %	July, %	August, %	September, %
1	<b>Nitrogen Content, %</b>				
	0.001	0.046	0.07	0.13	0.183
2	<b>Phosphorous Content, %</b>				
	0.00025	0.014	0.021	0.046	0.009
3	<b>Potassium Content, %</b>				
	0.456	0.528	0.34	0.509	0.359
4	<b>Organic Matter Content, %</b>				
	0.06	0.532	0.139	1.42	1.06
5	<b>Total Organic Carbon Content, %</b>				
	0.035	0.31	0.081	0.82	0.61
6	<b>Clay Content, %</b>				
	0.015	0.023	0.025	0.022	0.032
7	<b>Silt Content, %</b>				
	0.023	0.031	0.033	0.032	0.034



**Table 4: Regression Test for Input and Output Values of Various Parameters**

**t-Test: Paired Two Sample for Means, Nitrogen**

	<i>Variable 1</i>	<i>Variable 2</i>	<b>Parameters</b>	<b>Input NH<sub>3</sub>-N from Waste Water, mg.</b>	<b>Output Nitrogen in sand sample, %</b>
Mean	3586.768	0.086	Initial, May	0	0.001
Variance	7155465	0.005107	June	6.96	0.046
Observations	5	5	July	6.87	0.070
Pearson Correlation	0.986964		August	7.26	0.130
Hypothesized Mean Difference	0		September	6.89	0.183
df	4				
t Stat	2.998268				
P(T<=t) one-tail	0.020005				
t Critical one-tail	2.131847				
P(T<=t) two-tail	0.04001				
t Critical two-tail	2.776445				

**t-Test: Paired Two Sample for Means, Organic Matter**

	<i>Variable 1</i>	<i>Variable 2</i>	<b>Parameters</b>	<b>Input OM from Wastewater, mg</b>	<b>Output OM in Sand Sample, %</b>
Mean	6458.936	0.6422	Initial, May	0.00	0.023
Variance	13201988	0.34596	June	62.70	0.031
Observations	5	5	July	34.70	0.033
Pearson Correlation	0.587721		August	48.20	0.032
Hypothesized Mean Difference	0		September	78.40	0.034
df	4				
t Stat	3.974884				
P(T<=t) one-tail	0.008236				
t Critical one-tail	2.131847				
P(T<=t) two-tail	0.016471				
t Critical two-tail	2.776445				



**t-Test: Paired Two Sample for Means, Clay**

	Variable 1	Variable 2
Mean	24662.23	0.0234
Variance	3.25E+08	3.73E-05
Observations	5	5
Pearson Correlation	0.869912	
Hypothesized Mean Difference	0	
df	4	
t Stat	3.056624	
P(T<=t) one-tail	0.018891	
t Critical one-tail	2.131847	
P(T<=t) two-tail	0.037783	
t Critical two-tail	2.776445	

Parameters	Input TSS from Wastewater, mg	Clay Output in sand sample, %
Initial, May	0.00	0.023
June	62.70	0.031
July	34.70	0.033
August	48.20	0.032
September	78.40	0.034

**t-Test: Paired Two Sample for Means, Silt**

	Variable 1	Variable 2
Mean	24662.23	0.0306
Variance	3.25E+08	1.93E-05
Observations	5	5
Pearson Correlation	0.871656	
Hypothesized Mean Difference	0	
Df	4	
t Stat	3.056623	
P(T<=t) one-tail	0.018891	
t Critical one-tail	2.131847	
P(T<=t) two-tail	0.037783	
t Critical two-tail	2.776445	

Parameters	Input TSS from Wastewater, mg	Output Silt in Sand Sample, %
Initial, May	0.00	0.023
June	62.70	0.031
July	34.70	0.033
August	48.20	0.032
September	78.40	0.034



## REFERENCES

1. **Francis D and R Fonseca** Recent and projected changes in climate patterns in the Middle East and North Africa (MENA) region. *Sci. Rep.*, 2024; **14(1)**: 1–25. <https://doi.org/10.1038/s41598-024-60976-w>
2. **Khairy S, Shaban M, Negm AM, Eldeen OW and EM Ramadan** Drainage water reuse strategies: Case of El-Bats drain, Fayoum Governorate, Egypt. *Ain Shams Eng. J.*, 2022; **13(5)**: 101681. <https://doi.org/10.1016/j.asej.2021.101681>
3. **Meena M A** Geographical Study of Deserts. *Eur. J. Innov. Nonform. Educ.*, 2023; **1(1)**: 2795–8612.
4. **Liu C, Liu F, Andersen, Wang G, Tian Y and Z Ye** Natural treatment of domestic wastewater and desert soil restoration using green soil amendments. *Authorea.Com*, pp. 1–15, 2022. <https://www.authorea.com/doi/full/10.22541/au.166889755.50958996>  
Accessed March 2024.
5. **Sahour H, Vazifedan M and F Alshehri** Aridity trends in the Middle East and adjacent areas. *Theor. Appl. Climatol.*, 2020; **142(3-4)**: 1039–1054. <https://doi.org/10.1007/s00704-020-03370-6>
6. **Saif O, Mezher T and HA Arafat** Water security in the GCC countries: challenges and opportunities. *J. Environ. Stud. Sci.*, 2014; **4(4)**: 329–346. <https://doi.org/10.1007/s13412-014-0178-8>
7. **World Health Organization.** Progress on sanitation and drinking water. 2014 <https://iris.who.int/handle/10665/112727> Accessed March 2025.
8. **Hussain MI, Muscolo A, Farooq M and W Ahmad** Sustainable use and management of non-conventional water resources for rehabilitation of marginal lands in arid and semiarid environments. *Agric. Water Manag.*, 2019; May, **221**: 462–476. <https://doi.org/10.1016/j.agwat.2019.04.01>
9. **Al-Saidi M and S Saliba** Water, energy, and food supply security in the Gulf Cooperation Council (GCC) countries risk perspective. *Water (Switzerland)*, 2019; **11(3)**: 1–20. <https://doi.org/10.3390/w11030455>
10. **Hua F, Xudong P, Yuyi L, Fu C and Z Fenghua** Evaluation of soil environment after saline soil reclamation of Xinjiang Oasis, China. *Agron. J.*, 2008; **100(3)**: 471–476. <https://doi.org/10.2134/agronj2007.0100>



11. **Wang T, Wang Z, Guo L, Zhang J, Li W, He H, Zong R, Wang D, Jia Z and Y Wen** Experiences and challenges of agricultural development in an artificial oasis: A review. *Agric. Syst.*, 2021; **193(February)**: 103220  
<https://doi.org/10.1016/j.agsy.2021.103220>
12. **Negm AM and MGA Eltarabily** Modeling of fertilizer transport through the soil, case study: Nile Delta. *Handb. Environ. Chem.*, 2017; **55(September)**: 121–157. [https://doi.org/10.1007/698\\_2016\\_88](https://doi.org/10.1007/698_2016_88)
13. **Loutfy NM** Reuse of Wastewater in Mediterranean Region, Egyptian Experience. 2010;183–213. [https://doi.org/10.1007/698\\_2010\\_76](https://doi.org/10.1007/698_2010_76)
14. **Vera-Puerto I, Valdés H, Bueno M, Correa C, Olave J, Carrasco-Benavides M, Schiappacasse F and CA Arias** Reclamation of Treated Wastewater for Irrigation in Chile: Perspectives of the Current State and Challenges. *Water (Switzerland)*, 2022; **14(4)**: 1–20.  
<https://doi.org/10.3390/w14040627>
15. **James K** Reuse of Wastewater in Desert Regions. 2024  
<https://repository.arizona.edu/bitstream/handle> Accessed May 2025.
16. **Abdelrahman MAE** *An overview of land degradation, desertification, and sustainable land management using GIS and remote sensing applications*, 2023; **34(3)**. Springer International Publishing.  
<https://doi.org/10.1007/s12210-023-01155-3>
17. **Gohil MB** Land Treatment of Waste Water, New Age International, 2000; 1-28.
18. Phosphorus removal from wastewater  
<https://www.lenntech.com/phosphorous-removal.htm> Accessed March 2025.
19. **Dwivedi A, Kumar P, Kumar P, Kumar Y, Sharma YK and AM Kayastha** Soil sensors: detailed insight into research updates, significance, and future prospects. Elsevier Inc., 2017. <https://doi.org/10.1016/B978-0-12-804299-1.00016-3>
20. **Zhao Y, Xue J, Wu N and RL Hill** An Artificial Oasis in a Deadly Desert: Practices and Enlightenments. *Water (Switzerland)*, 2022; **14(14)**: 1–12.  
<https://doi.org/10.3390/w14142237>