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Reclamation of Desert with Regular Application of Waste Water

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Abstract

Deserts around the world mostly do not have plants and are ever- expanding their area each year. There is shortage of food and prevalent hunger around the world mostly in the African countries that have desert. The waste water is not properly managed in those places and it causes disease outbreaks. So, the problems of desertification, waste water management and hunger have to be addressed by the world community. This thesis work tries to explore a possibility of reclamation of deserts with regular application of waste water. The results obtained from a four months long test are very encouraging and it can be easily concluded that the deserts can be reclaimed by application of waste water and it will relieve the desert community from the burden of costly treatment of waste water as well. In turn, they will, to some extent, get rid of water borne diseases and the reclaimed land could be used in future to produce more food to feed the hungry community- positively impacting directly to food security of the focused community.

Keywords : Desert Reclamation, Waste Water Treatment, Recycling, Hunger, Diseases

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1. Introduction

1.1 Background

The scarcity of water resources and the growing threat of desertification are global environmental concerns that pose significant challenges to sustainable development. In many arid and semi-arid regions, including Middle East, North Africa and even Deserts in China and Mongolia as well. The availability of fresh water is limited, while the expansion of deserts continues to degrade valuable land and ecosystems. These pressing issues necessitate innovative approaches to water management and desert reclamation.

Deserts are characterized by arid and extreme environmental conditions, such as high temperatures, low humidity, and limited water availability. These factors significantly influence the growth and survival of plants in deserts. The primary reason for the scarcity of plants in deserts is Water Scarcity and other reasons are; High Evaporation Rates due to less relative humidity, Sandy and Unstable Soil, Temperature Extremes, Competition for Resources and Adaptations [Levin, (2013)]

The treatment and application of waste water offer a promising solution to address both water scarcity and desertification. Waste water, which includes domestic, industrial, and agricultural effluents, is often discarded without adequate treatment, resulting in pollution and a waste of potential resources. However, when properly treated, waste water can be a valuable source for moisture enhancement in the deserts and ecosystem restoration in arid regions, supporting sustainable agriculture and mitigating desertification.

In the context of Middle East and North Africa (MENA), which experiences water scarcity and faces the risk of desertification, there is a need to explore the feasibility and effectiveness of natural treatment of waste water with its application in desert reclamation. By conducting research on a test plot that simulates desert-like conditions, valuable insights can be gained into the potential benefits, challenges, and environmental impacts of utilizing untreated waste water for reclamation purposes. It is important to note that the formation of deserts is a complex and multifaceted process influenced by a combination of factors. The specific characteristics and formation mechanisms can vary for different deserts around the world [Meena, 2023].

1.2 Literature Review

The study aims at converting the sand into sandy soil and thus, composition of sandy soil must be known.

1.2.1 Sandy Soil and it's Composition

Soil types can be complex and vary significantly based on regional factors. A general overview of Sandy Soil is as following:

Mineral Matter: Primarily consists of sand particles.

Organic Matter: Generally lower in organic content.

Water: Drains quickly due to large pore spaces between sand particles.

Air: Good drainage and aeration.

The composition of sandy soil can vary based on factors such as location, climate, and land use. Here's a general range of the fractions of minerals, organic matter, water, air, and silt typically found in sandy soil:

a. **Minerals**: Sand Particles: Sandy soil is primarily composed of sand-sized particles, with a diameter between 0.05 mm and 2.0 mm. The sand fraction makes up the majority of the soil, ranging from around 70% to 90% or more.

b. **Organic Matter**: The organic matter content of sandy soil is generally lower compared to other soil types. It might range from about 0.5% to 3% or more. Organic matter contributes to soil fertility and water-holding capacity.

c. **Water**: Sandy soil has relatively low water-holding capacity due to the large pore spaces between sand particles. The water content might range from 5% to 20% when fully saturated.

d. **Air**: Sandy soil provides good drainage and aeration due to its large particle size. The air-filled porosity might range from 30% to 50% or more, depending on factors like compaction and water content.

e. **Silt and Clay**: Sandy soil generally has a very low proportion of silt and clay-sized particles. The silt content might range from 1% to 10%, while the clay content is typically less than 5%.

1.3 Objective

1.3.1 Research Aims

The research aims at investigating the following key aspects:

a. **Reclamation of Desert**: The research will examine the impacts of continuous application of untreated waste water on soil quality and ecosystem dynamics in a simulated desert-like environment.

b. **Waste Water Treatment**: Waste Water Treatment is secondary aim of this research. It can be considered as a natural outcome during the process of reclamation.

The outcomes of this research have significant implications for water resource management, land restoration, and environmental sustainability in arid and semi-arid regions facing similar challenges. Ultimately, the research aims to contribute to the development of sustainable approaches for water utilization and land management, fostering resilience and combating desertification in arid regions.

1.3.2 Research Objectives

The following are the research objectives:

a. To evaluate the potential of untreated waste water for desert reclamation by studying its effects on soil quality in a simulated desert-like environment.

b. To provide evidence-based recommendations for the integration of waste water treatment and reclamation strategies in arid and semi-arid regions, with an experiment conducted in a simulated test plot in Kathmandu, Nepal.

1.3.3 Research Questions:

a. How do the findings from this research contribute to the broader understanding of waste water utilization and desert reclamation in arid and semi-arid regions?

b. How does the application of untreated waste water influence soil quality parameters, including soil composition and nutrient levels, in a simulated desert-like environment?

These research objectives and questions provide a framework for the potential benefits and challenges of utilizing raw waste water for desert reclamation and waste water treatment. They guide the study towards generating knowledge and insights that can inform decision-making and contribute to sustainable water resource management and land restoration efforts.

The previous research on desert reclamation and waste water utilization has provided valuable insights into the potential of using treated waste water as a resource for land restoration in arid regions. But, none of those have used untreated waste water so far.

The benefits, challenges, and risks associated with waste water utilization has been explored and it has contributed to the development of sustainable strategies for desert reclamation. However, there is a need for further research to address specific regional variations, optimize treatment processes, and develop tailored approaches to suit the diverse desert environments worldwide [AbdelRahman, 2023].

Desert soil consists of almost 90- 95% of sandy soil in low-rainfall regions. The nitrogen content is low and organic matter is also negligible but, is rich in calcium carbonate and phosphate and that makes it infertile. If nitrogen could be available in the form of nitrates from fertilizer and proper irrigation, in addition to the already-present phosphates makes it useful in growing crops such as barley, rape, cotton, wheat, millets, maize, and pulses [Dwevedi et al., 2017].

The proposed research focusses on utilization of raw waste water and see the results.

1.4 Scope and limitations

1.4.1 Scope

Geographic Scope: The study is being conducted in Kathmandu, Nepal, as the research site for investigating waste water treatment and reclamation of deserts. The geography of deserts and lush green Kathmandu is entirely different. It involves the selection and establishment of a test plot that is prepared simulating desert-like conditions within the test area.

Desert Reclamation: The study assesses the potential of using raw waste water for desert reclamation by examining its effects on soil quality, vegetation growth, and ecosystem dynamics. It aims at providing insights into the viability and success of utilizing untreated waste water for land restoration in arid environments.

1.4.4 Limitations of the Study:

a. **Generalizability**: The research findings and recommendations may have limitations regarding their generalizability to other regions or contexts beyond Kathmandu, Nepal. The specific environmental, climatic, and socio-economic conditions of the study area may, somehow, influence the results and a customized approach should be adopted when applying the findings to different climatic and geographic locations.
b. **Time Constraints**: The study has faced limitations in terms of the time available for research activities and data collection as the beginning 2 years were seriously affected by COVID19 pandemic. Conducting long-term experiments and monitoring processes are essential for capturing the full effects of waste water application on desert reclamation. However, duration of the study has been constrained by practical time limitations

of submission of this draft thesis report and resources availability.

c. **Scale of Implementation**: The research focuses on a test plot of just 1 square meter area within Kathmandu, Nepal owing to the cost of construction of a larger test plot.
d. **In-situ Variations**: Consequently, the findings may not fully represent the potential outcomes and challenges associated with implementing waste water treatment and reclamation on a larger scale. The scalability and practicality of the proposed approaches should be further evaluated in the context of broader implementation scenarios, i. e. at the hot desert itself.
e. **Ethical Considerations**: The study involves the use of waste water and potential environmental impacts. It is important to adhere to ethical guidelines and regulatory frameworks for waste water treatment, land use, and environmental protection. Limitations could have arisen in terms of balancing scientific research objectives with ethical responsibilities and ensuring compliance with relevant regulations. But, it was not an issue as the premise itself is a site for waste water treatment of Kathmandu.
f. **Technical Limitations**: The study may have encountered technical limitations related to waste water treatment technologies, data collection methods, and analysis techniques. These limitations could have affected the accuracy and precision of the results obtained and may have required careful consideration and appropriate measures to mitigate potential biases or uncertainties. No test bores were drilled to collect the infiltrated applied waste water as there is a science-backed and an established procedure of waste water treatment by land application. The waste water that percolated below the test plot was considered well-treated because of the established procedure of waste water treatment. It was also considered not necessary because the deserts have 100s of meters of thick sand layers and the temperature is also very high helping the applied waste water get treated in few hours during percolation.

Despite these limitations, the study offers valuable insights into reclamation of deserts in a desert-like simulated model (a test-plot) and waste water treatment in Kathmandu, Nepal. It contributes to the existing knowledge base on sustainable water resources management, land restoration practices, and the potential of waste water utilization in arid environments.

2. Materials and Methods

2.1 Research design and approach

The research was designed to be conducted in 2020 but, the COVID 19 pandemic (late 2019-beginning of 2023) delayed the research at field level. The researcher tried to find out a place in nearby deserts of India to conduct the research at field level. But, the regulations of the Government of India were very difficult to a foreigner to fulfil. Then, the researcher tried to find space in Ethiopia and seek some donor support for the research but, again it failed because of lack of interest of the donors. The researcher even presented this idea to

United Nations' Convention for Combatting Desertification (UNCCD).

This UN Agency is custodian of Sustainable Development Goal (SDG) target 15.3: "By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world." In the beginning they were very much interested. But, it could not, somehow, materialize. The researcher floated this idea through LinkedIn to garner support and funding. A Professor of South Africa was interested and she passed on a contact for further discussion. But, that contact person did not respond properly.

So, this research got delayed. Finally the Researcher aimed at replicating desert- like condition in Kathmandu with an experimental set up at Bagmati Sewerage Treatment Plant in Kathmandu, Nepal.

2.2 Study area description and selection of the test plot

A continuous supply of waste water was needed for this research and thus, the research plot was selected just next to the inlet portion of Bagmati Sewerage Treatment Plant of Kathmandu Valley near the international airport.

2.3 Simulation of desert-like conditions

A desert is a barren and arid region characterized by a lack of significant vegetation and limited precipitation. It is a geographical area that typically receives very little rainfall, making it difficult for plants and animals to thrive. Deserts often have extreme temperature variations, with scorching hot days and cool nights.

Deserts are generally classified based on their specific characteristics and location. Some common types of deserts include; Hot deserts, Cold Deserts, Coastal Deserts and Polar Deserts. The research is focused to the Hot Deserts only.

These Hot deserts, such as the Sahara Desert in Africa and the Arabian Desert in the Middle East, experience high temperatures during the day, often exceed 100°F (38°C). These have sparse vegetation and are normally composed of sandy or rocky terrain.

Aridity because of high temperature, sand as the bed and no vegetation cover at the surface were the three characteristics to be simulated. The experimental set up is described below.

2.4 Waste water treatment techniques and processes

The main treatment parameters for a waste water are Bio- chemical Oxygen Demand (BOD), Total Suspended Solids (TSS) and Nitrogen (N). The waste water treatment technique adopted was surface application of waste water on the sand bed of the test plot. With the passage of time it would percolate down to the sub- surface and get treated naturally. The suspended organic matters would get retained by the sand media and that would turn into humus like substance. Humus material is good for any soil as it harbors many micro- organisms that can break organic matters into inorganic and these are readily uptaken by the plan roots. The suspended inorganic substance (mostly silt) of the waste water would also get retained in the sand media and help the sand turn into soil with passage of time.

Some portion of the waste water would get evaporated because of high temperature maintained in the test plot in the day time to simulate summer temperature condition of the hot deserts. The Nutrients (Nitrogen, Phosphorous and Potassium- N, P, K) would also partially get retained in the sand media and make the sand rich of nutrients that could be helpful to the vegetation later.

2.5 Experimental setup and data collection methods

2.5.1 Experimental Set up

One square meter pit was created by excavating (Length = 1m and Breadth = 1m) of earth surface near the inlet of the waste water treatment plant up to a depth of 0.27m surrounded by single brick cemented wall from all four sides. A suitable area for the test plot was selected to ensure it was representative of the desert landscape. The area was cleared of debris and vegetation that could have interfered with the experiment. A test pit of volume Length (L= 1.092075 m) × Breadth (B= 1.092075 m) × Depth (D= 0.27 m) = 0.322 Cubic meter or 322 liters was excavated. A single brick masonry wall of 5 layers of bricks was constructed around the excavated pit to make the inner dimension up to ground level as L= 1 m, B = 1 m and D = 0.27 m giving a volume of 0.27 Cubic meters or 270 liters. Sand was filled up to a height of 4 brick masonry layers i. e. up to ground layer to keep one brick masonry layer as free board. The sand bed was levelled up to the 4 layers of bricks to create a consistent and uniform surface. A sample of the sand was collected in a plastic bottle and sent to the laboratory for analysis for its different composition like; Nitrogen (N), Phosphorous (P), Potassium (K), Organic Matter, Total Organic Carbon (TOC), Clay and Silt that are required to see the changes necessary for this research.

A roofing cover was provided to the test pit to avoid rainfall. The roofing cover was made of Iron frame covered by 50 micron thick plastic sheets on top and half of the sides. The lower open portion was fenced with Chicken wire mesh to avoid animals from tampering the test site. The enclosure thus prepared was provided with 10 nos. of 200 Watts capacity bulbs hanging from the frame at a height of 30 cms. from the sand surface to make the environment as hot as the desert. The temperature measured in different times varied from 450 C to 550 C. The temperature range exactly simulates the thermal condition of the deserts of India, middle-east and North Africa.

An Iron frame (Length = 1.5 m, Breadth = 1.5 m and Height = 2.0 m) made of angles and MS flats with four legs was fabricated and erected to cover the test plot with polyethylene sheet of 500 micron thickness as roofing and wall material. A photograph is shown below in 〈Figure 1〉:

The following 〈Figure 2〉 shows application of waste water and measurement of ambient temperature at the test plot:

〈Figure 1〉 The test model with all the bulbs lit

〈Figure 2〉 Application of Waste water & Ambient Temperature Measurement

2.5.2 Application of Waste water

The Electric Motor used for pumping waste water to apply had a discharge capacity of 10,000 liters per hour. An average time of 1 minute and 21 seconds took to fill the test plot. The maximum time taken was 1 minute and 30 seconds and the minimum was 1 minute 10 seconds. The average volume applied every day was 222 liters. The volume depends on factors such as the plot size, desired application rate, and the ability of the sand bed to absorb waste water. The Motor with plastic pipe was used to apply the waste water evenly over the entire test plot surface every day. It was ensured that the application was consistent and uniform to maintain the reliability of the experiment.

2.5.3 Data Collection

Two types of data have been collected as following:

(1) Initial Characteristics of Waste water

The main parameters that were collected for 4 months are as shown, as an example, in the following 〈Table 1〉:

(2) Measurement of Changes in Composition of Sand:

Monthly periodic (June 20, July 20, August 20 and September 20 of the year 2023) soil samples from the test plot were taken in a half liter plastics jar to analyze the changes in the composition and characteristics of the sand media with the application of waste water. The soil samples were analyzed for their physical and chemical properties. Important parameters include: pH, Temperature, NaCl content, Total Nitrogen, Total Phosphorous, 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. The changes over time (each month) were compared to the previous records.

〈Table 1〉 Daily Representative Characteristics of Applied Waste Water

Raw Sewage (Composite)						
Date	pH	BOD5	COD	TSS	NH3-N	O & G
	-	mg/L	mg/L	mg/L	mg/L	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

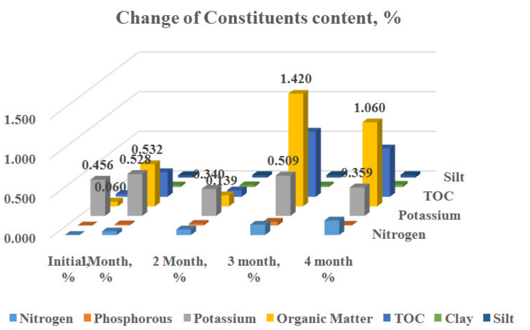
3. Results and Discussion

3.1 Data Illustration and Explanation

The following ⟨Table 2⟩ shows the test records of the sand media in the beginning and in 1 month time interval each for 4 consecutive months:

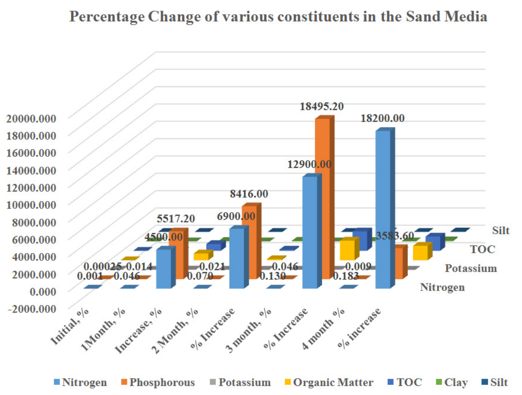
MS Excel sheet has been used to analyze the data to identify trends and patterns related to changes in the sand sample of the bed. Bar charts have been drawn to see the changes of concentration of various recorded parameters.

The corresponding Bar chart of the ⟨Table 2⟩ is shown below in ⟨Figure 3⟩:



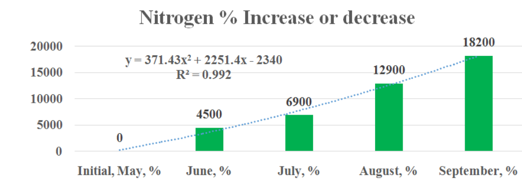
⟨Figure 3⟩ Cumulative Changes of all the parameters after each month of waste water application for 4 months

The following ⟨Table 3⟩ shows the Increment percentage of each constituents and similarly the ⟨Figure 4⟩ depicts the data in a graphical format:



⟨Figure 4⟩ Increment Percentage of all the Parameters after Each Month of Waste Water Application for 4 Months

The following bar charts in ⟨Figure 5⟩ clearly show the changes in the individual constituents of the sand bed after regular application of waste water to it as per above ⟨Table 4⟩:



⟨Figure 5⟩ Changes in the Nitrogen content after regular application of wastewater

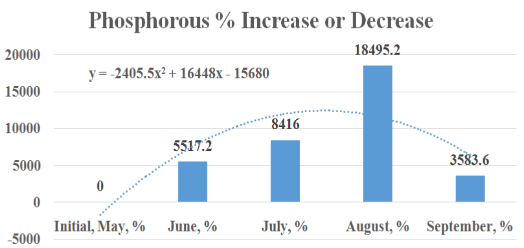
⟨Table 2⟩ Test results of the sand media from the Lab

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	12900.00	0.183	18200.00
Phosphorous	0.00025	0.014	5517.20	0.021	8416.00	0.046	18495.20	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 4〉 Increment Percentage of Each Constituents

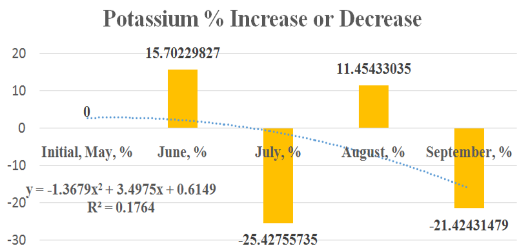
1. Nitrogen Content, %				
Initial, May, %	June, %	July, %	August, %	September, %
0.001	0.046	0.070	0.130	0.183
2. Phosphorous Content, %				
0.00025	0.014	0.021	0.046	0.009
3. Potassium Content, %				
0.456	0.528	0.340	0.509	0.359
4. Organic Matter Content, %				
0.060	0.532	0.139	1.420	1.060
5. Total Organic Carbon Content, %				
0.035	0.310	0.081	0.820	0.610
6. Clay Content, %				
0.015	0.023	0.025	0.022	0.032
7. Silt Content, %				
0.023	0.031	0.033	0.032	0.034

Nitrogen has increased by 4500% by the end of one month, 6900% by the end of second month, 12900% by the end of third month and by 18200% by the end of fourth month of application of waste water.



〈Figure 6〉 Changes in the Phosphorous content after regular application of wastewater

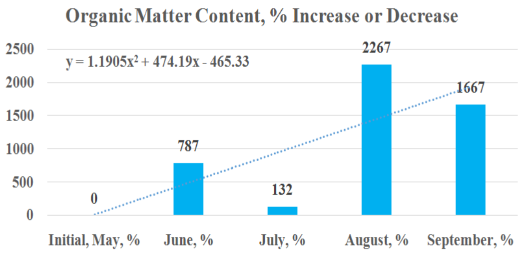
Phosphorous (P) has increased by 5517% by the end of first month, by 8416% by the end of second month, by 18495.2% by the end of the third month and by a sudden drop to 3583.6% was seen by the end of fourth month of application of waste water. But, still it is higher than that of initial level.



〈Figure 7〉 Changes in the Potassium content after regular application of wastewater

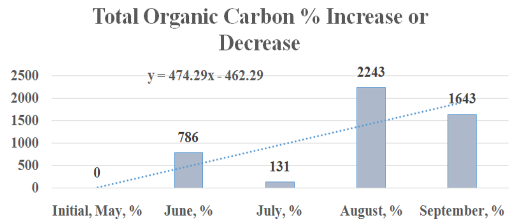
Potassium has increased by 16% in the first month of application but, it decreased to below 25% in the second month and it again recovered by 11.5% at the end of the third month and it again decreased by 21.4% at the end of fourth month of application of waste water. The decrease in the Potassium content in the second month may be because of peak rainy season (last 11 days of June and beginning 19 days of July is the peak monsoon period in Nepal). The heavy rainfall in Kathmandu may have led to dilution in content of potassium in the waste water and the regular application of dilute waste water could have leached out the already present potassium in the research plot.

The monsoon season extended till October in the year 2023 in Kathmandu, Nepal and it could be the reason for further decrease in Potassium content in the test plot as the waste water was highly diluted. A further field level research is necessary to know the exact reason of variable results every next month.



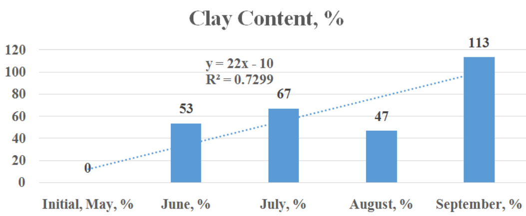
〈Figure 8〉 Changes in the organic matter content after regular application of wastewater

The organic matter has increased by 787% in the first month of waste water application but, it went down to 131.7% in the second month, it recovered back to 2267% at the end of third month and at the end of the fourth month it slightly decreased to 1667%. The reason of decrease in the second and fourth month could be the same as that mentioned above in case of Potassium. The fraction of organic matter at the end of 4 months is 1.06% as compared to 0.06% in the beginning. That is an increment of 1667% as compared to the sand sample at the beginning of the research.



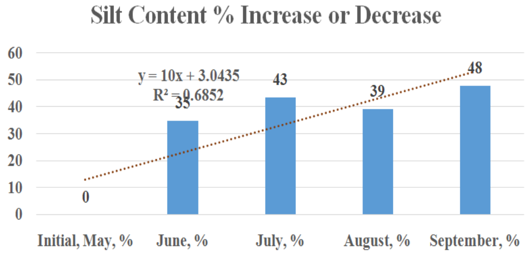
〈Figure 9〉 Changes in the organic Carbon after regular application of wastewater

The Total Organic Carbon (TOC) has increased by 786% in the first month of waste water application but, it went down to 131.4% in the second month, it recovered back to 2242.9% at the end of the third month and again slightly went down at the end of the fourth month. The fraction of TOC at the end of 3 months is 0.61% as compared to 0.035% in the beginning of the research. Thus, it is an increment of 1643% as compared to that in the beginning.



〈Figure 10〉 Changes in the clay content after regular application of wastewater

The content of clay has increased by 53% with a month of application of waste water and it further increased to 66.7% at the end of second month but, it went down slightly at the end of the third month to 46.7%. But, again it jumped to 113% at the end of the fourth month. The fraction of clay at the end of fourth month is 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 11〉 Changes in the silt content after regular application of wastewater

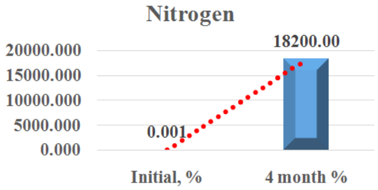
The content of silt has increased by 35% in the first month of application of waste water and it further went up to 43.5% in the second month but, came down slightly at the end of third month and again increased to 48% at the end of fourth month. The fraction of silt in at the end of fourth month of application of waste water is 0.034% as compared to 0.023% in the beginning of the research and that is an increment of 48% and the result supports the hypothesis of the research.

3.2 Data Interpretation

Interpretation of the results to draw conclusions about the impact of daily wastewater application on the properties of sand bed and its potential for desert reclamation have been presented as following:

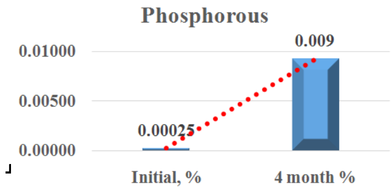
A. **Nitrogen**: The initial concentration of Nitrogen (N) was a mere value of 0.001% in the total content of the sand sample tested in the lab. Within 4 months of daily application of waste water, the concentration became 0.183% and that is a huge rise of 18200%. Such a level of increase in first prime nutrient for plant growth is definitely a very positive sign for the reclamation of sand mass.

The following bar chart 〈Figure 12〉 shows the increment graphically:



〈Figure 12〉 Showing comparison of initial and 4 months data of Nitrogen

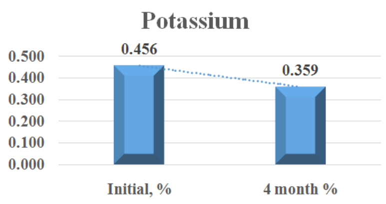
B. **Phosphorous**: The initial concentration of Phosphorous (P) was only 0.00025% in the total content of the sand sample tested in the lab. Within 4 months of application of waste water daily the concentration became 0.009% and that is a huge rise of 3583%. Such a level of increase in second prime nutrient for plant growth is definitely a very positive sign for the reclamation of sand mass. The following 〈Figure 13〉 shows the increment graphically:



〈Figure 13〉 Showing Comparison of Initial and 4 Months Data of Phosphorous

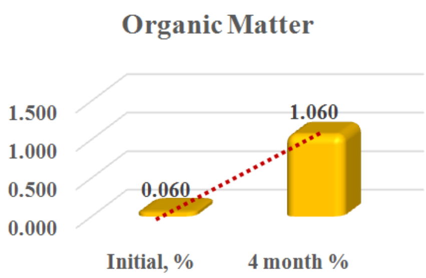
C. **Potassium**: The initial concentration of Potassium (K) was 0.45643% in the total content of the sand sample tested in the lab. Within 4 months of daily application of waste water, the concentration became 0.359% although it had risen to 0.509% at the end of third month. It is a fall of 21.42% and it could be because of prolonged monsoon diluting the waste water of Kathmandu.

The following 〈Figure 14〉 shows the increment graphically:



〈Figure 14〉 Showing Comparison of Initial and 4 Months Data of Potassium

D. **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 waste water, the concentration became 1.06%, a rise of 1667% although it had reached 1.42% in the third month and that 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 following 〈Figure 15〉 shows the increment graphically:



〈Figure 15〉 Showing comparison of initial and 4 months data of Organic Matter

D.1 **Result**: The equation obtained for the best fit curve of the bar- chart is:

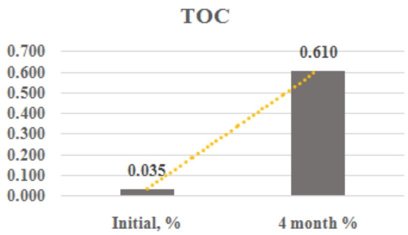
$$y = 0.288x - 0.2242$$

Where: y is percentage of organic matter in the sand bed and
x is number of months of application of waste water.

The minimum percentage of Organic matter for a sand to become a sandy soil is less than 0.5% as already mentioned. So, the organic matter content of the sand has risen from 0.006% to 0.6398% in just 3 months and in 4 months it has reached 0.9278% and it will keep on increasing with further addition of waste water daily. So, Organic matter is more than enough for reclamation of the sand bed.

E. **Total Organic Carbon**: The initial concentration of Total Organic Carbon (C) was only 0.035% in the total content of the sand sample tested in the lab. Within 4 months of daily application of waste water, the concentration became 0.61%, an increase of 1643%, although it was 0.82% at the end of 3 months and that was a rise of 2243%. Such a huge level of increase in organic carbon is a very positive sign for the reclamation of sand mass as the cohesive property of the sand and the health of the soil will increase and it will be able to hold the roots of plants.

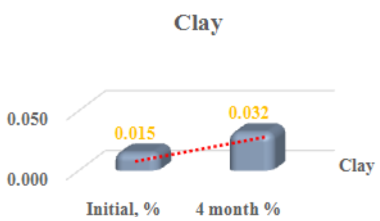
Further, it will be able to harbor bacteria and earthworms and other biota that are essential for soil fertility and conversion of organic matters to inorganic forms. Such inorganic nutrients will be taken- up by plant roots for their growth. The following 〈Figure 16〉 shows the increment graphically:



〈Figure 16〉 Showing Comparison of Initial and 4 Months Data of TOC

It is proportional to the fraction of Organic matter and it has followed the similar trend.

F. **Clay**: The initial concentration of Clay was only 0.015% in the total content of the sand sample tested in the lab. Within 4 months of daily application of waste water, the concentration became 0.032% and that is a rise of 113.33%. Such a level of increase in Clay content is a positive sign for the reclamation of sand mass as the cohesive as well as binding property of the sand will increase and it will be able to hold the roots of plants. The following 〈Figure 17〉 shows the increment graphically:



〈Figure 17〉 Showing comparison of initial and 4 months data of Clay

F.1 **Result**: The equation obtained for the best fit curve of the bar- chart is;

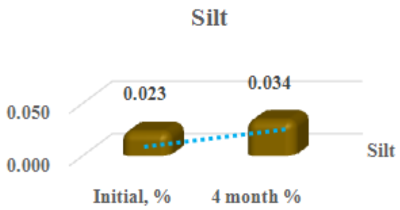
$$y = 0.0033x + 0.0135$$

Where; y is percentage of clay in the sand bed and
x is number of months of application of waste water.

The minimum percentage of clay for a sand to become a sandy soil is less than 5% as already mentioned. So, the clay content of the sand has risen from 0.015% to 0.032% in 4 months and it will keep on increasing with further addition of waste water daily. Any number below 5% is good enough for the sand to become a sandy soil.

It will take 298 months of continuous application of waste water for the clay content to be 1% in the sandy soil. An increase in flow rate, thus volume of daily application of waste water shall definitely shorten the time period for reclamation.

G. **Silt**: The initial concentration of Silt was 0.023% in the total content of the sand sample tested in the lab. Within 4 months of daily application of waste water, the concentration became 0.034% and that is 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 property of the sand will increase and it will be able to hold the roots of plants. The following 〈Figure 18〉 shows the increment graphically:



〈Figure 18〉 Showing Comparison of Initial and 3 Months Data of Silt

G.1 Result: The equation obtained for the best fit curve of the bar- chart is;

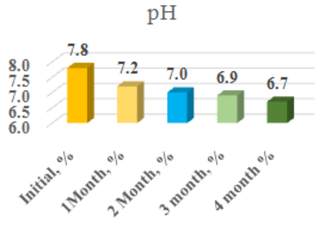
$$y = 0.0023x + 0.0237$$

Where; y is percentage of clay in the sand bed and
x is number of months of application of waste water.

Anything above 1% of Silt in the sand is good enough for it to turn into sandy soil. A continuous application of waste water will keep on increasing the silt content of the sandy soil.

The current rate of application of waste water was just around 2 minutes a day. 424 months of continuous application is required to reach a concentration of 1% of silt with this rate of flow. So, an increased flow and thus, the volume of application of waste water will definitely bring down the time period of reclamation.

H. pH: The initial pH of the sand sample was 7.8 and it has been decreasing 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 decrease of pH is favorable for the hypothesis. The following ⟨Figure 19⟩ shows the Bar Chart of pH of all four months:



⟨Figure 19⟩ Gradual Decrease of pH Every Month

3.3 Adjusting the Experiment (if needed)

- There was no need of adjustment in the experimental set up as the desired results were obtained.

3.4 Continuation and Long-Term Monitoring

- Daily application of wastewater was continued and data collected for over an extended period of 4 consecutive months to understand the trend of changes because of 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.

It was essential to maintain consistent and accurate data collection throughout the experiment to ensure the reliability of the study's findings. Additionally, adherence to ethical and environmental guidelines were also crucial to minimize potential negative impacts on the surrounding environment during the experimental process.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Summary of the study's major findings

The results of the tests obtained in 120 days of continuous application of waste water in the test plot of sand bed has shown increase in all the parameters (Nitrogen-N, Phosphorous-P, Organic matter, Total Organic Carbon-TOC, clay and silt), except the potassium- K and pH that were measured. Decrease in pH is highly favorable for plants.

4.2 Contributions to the field of waste water treatment and desert reclamation

The result so far is very promising and it could have a great impact in reclamation of deserts in future.

4.3 Implications for future research and practical applications

Future research can be done in the desert itself and the results observed in this research shall be able to guide the field research.

4.4 Recommendations for policy and practice related to waste water management and desert reclamation

The countries that are located near or within deserts need to make a policy of utilizing vital resources present in the waste water and reclaim the deserts for beneficial purpose both to humans as well as the environment.

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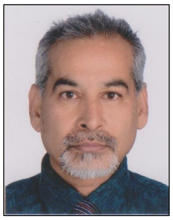
Author Profile



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