Impact of Sodium Carbonate on Seepage Reduction in Farm Irrigation Ponds

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Abstract

Rainfall does not always meet crop water demands in many areas, a problem that climate change is expected to exacerbate. Considering the high rate of seepage in earth ponds, there is an urgent need to improve irrigation efficiency. This research evaluates an economic layer based on a simple technology to minimize seepage at the bottom. Therefore, it is recommended that sodium salts be used in combination with soil at the bottom of irrigation ponds. Three types of slightly plastic loamy soils were selected with clay contents of 20%, 15%, and 10%. The soil textures were determined first, followed by their chemical properties. Sodium carbonate was utilized at 0%, 2%, 4%, 6%, 8%, 10%, and 12% by soil weight. Finally, the falling head permeability test, SEM analysis, pH, and compaction tests were conducted. Based on the results, the maximum seepage reduction was due to the use of soil sample #3. The 10% sodium carbonate caused the maximum reduction in permeability. For the pH and compaction test results, the addition of sodium carbonate respectively decreased soil permeability and increased soil compaction. Overall, the results indicate that this pond sealer can effectively reduce seepage in farm irrigation ponds.

Key Words: Farm irrigation pond, Sodium carbonate, Permeability, Seepage losses, Pond sealer.

1. Introduction

Although supplemental irrigation can help increase and stabilize agricultural yields, water requirement for irrigation has frequently resulted in groundwater overuse. Ponds on farms might provide a more long-term source of water. The seepage reduction in the irrigation ponds is a practical way of preserving the water

resources available. With careful management, water losses can be minimized and irrigation efficiency can be improved. An irrigation pond is a man-made pond used for capturing, distributing, and storing water for various agricultural purposes and the seepage reduction in it is a very important issue. Therefore, it is critical to reduce seepage in the soils that make up these ponds.

Several studies have recently been conducted on sustainable water resources management (Haider et al.) [1] and the modification of geotechnical characteristics of canal embankments to reduce seepage (Guilia et al.) [2] and improve shear strength (Zhou et al.) [3], (Matthew et al.) [4], (Karimi et al.) [5]. Research was also conducted on the design of irrigation ponds for a high and stable yield in various climates and on risk-coping attitudes (Deng et al.) [6]. Seepage flow properties with biofilm development in porous media with various filter morphologies were investigated in an experimental study (Bennett and Warren) [7]. Matthew and Akinyele [8] studied permeability for two types of subsoil in combination with NaCl and $CaSO_4$. They showed that NaCl increases soil permeability while $CaSO_4$ decreases it. Deng et al. [9] investigated the impact of Metakaolin on permeability coefficient of cement-stabilized soft clays using the flexible wall permeameter. They showed that as the MT percentage increased the hydraulic conductivity decreased. Bennett and Warren [10] examined livestock feedlot effluent seepage in ponds and recommended using a low-concentration fine to seal ponds. They observed a reduction in the hydraulic conductivity. Zhou et al. [11] investigated how a mixture of sodium bentonite and clay influenced the permeability of riverbeds. The best alternative was a mixture of 19% bentonite and 81% clay Gupta et al. [12] studied permeability in stratified soils. They found that end layer thickness affects stratified soils permeability. Estabragh et al. [13] examined seepage velocity and force in silty soil. The results showed that reinforcing fibers decrease seepage velocity and force. Ghasemzadeh et al. [14] investigated the use of sodium bentonite to minimize channel seepage. Wang et al. [15] studied impermeability, unconfined compressive strength, and mechanisms of cemented silty soil. The results revealed that the UCS and impermeability enhanced in cemented silty soil including coal-bearing metakaolin. Elmashad [16] investigated two types of swelling clay and a type of bentonite. The permeability and infiltration of soils decreased as the plasticity properties of the soils increased. As the bentonite ratio was increased, the permeability and cohesion decreased and increased, respectively. Holthusen et al. [17] investigated the soils of clay, loamy, and fine loamy sand under No-Tillage (NT), Native Forest (NF) and Native Grassland (NG) conditions. They surveyed density, porosity, water retention, air permeability and saturated hydraulic conductivity. The results showed that soil compaction had a significant impact on the soil under

NT conditions. Eltarabily et al. [18] utilized geotextile to investigate the stability of soil canal side slopes as soil permeability changes. The results indicated, while the geotextile is significant in seepage control, the geotextile thickness specifications and requirements are also significant. Liu and Jeng [19] simulated the permeability of different-shape particles and different-surface particles in porous media. The results proved that effect of shape and surface of the particles is ignorable. They proposed a mathematical equation based on geometrical variables. Rosli et al. [20] researched shear strength and permeability coefficient of Lateritic soils treated by compaction in standard and modified proctor energy ranges from 596 to 3576 kJ/m3. The results show an increase in maximum dry density and shear strength, 5% to 15% and 48% to 128% respectively, as well as a decrease in permeability coefficient from 40% to 73%. Shah et al. [21] analyzed seepage for canals lined with concrete. Yuguda et al. [22] proposed a model for water losses in soil canals. Tabarsa et al. [23] investigated temperature changes on soil permeability. They obtained an equation for the changes. Mollamahmutoglu et al. [24] investigated properties of microfine and ordinary Portland cements treated high plasticity clayey soil (HPCS). They have shown that soil properties, including permeability, are thus improved.

In this research, an economic mixture based on a simple technology (as a pond sealer) is evaluated to minimize seepage in irrigation ponds. Since sodium carbonate diverges clay particles and decreases permeability by reducing porosity, it is recommended that sodium salts be used in mixed with soil in irrigation ponds. Sodium carbonate is therefore selected as a salt which easily absorbs sodium into soil particles. In the materials and method section, the relevant chemical processes are described and soil samples and their physical properties are demonstrated using falling head permeability test, Scanning Electron Microscope (SEM) analysis, PH test, and compaction test. In the results and discussion section, the results of the experiments are summarized as tables, graphs, and counter curves. In the end, the conclusions are released in the last section.

2. Materials and Method

Given, on the one hand, the growing demand for water for agricultural and drinking consumption and, on the other hand, the existence of many difficulties in seeking new sources, the conservation of extracted water has become a significant issue worldwide. We will soon observe that the best way to maximize the amount of water available naturally is to use the water that is already available in different ways to reduce waste and improve application efficiency. One of the most effective ways to make the most of the water available for

agricultural use is to reduce water seepage and leakage. According to studies, water loss in irrigation systems is extremely high. Under normal conditions, the percentage of seepage and leakage in irrigation pond, small canals and farm streams is higher than in large water conveyance canals and irrigation ponds, according to observations and available reports. Water losses by seepage, leakage, and use by hydrophilic plants, for example, are estimated to be about 20% at 1.6 kilometers in canals with a canal capacity of 30 to 40 liters per second. It should be noted that pond or canal lining does not fully prevent seepage and leakage; however, according to some reports, linings can reduce 60% to 80% of water loss in unlined ponds or canals. Based on this and other previous experiments, in a pond or canal that is completely lined, water losses do not exceed 30 liters per square meter of pond or canal surface per day. Aquatic plants growing in unlined ponds and canals often consume a large amount of water inside the pond or canal, to the point that their water intake can be 50% to 100% higher than farm plants in some cases. As a result, while pond or canal lining is very effective at reducing water waste, strategies must be established to reduce waste even further (Chen et al.) [25], (USBR) [26].

The use of low permeable layers at the bottom of the pond, which can help reduce the permeability of the pond bottom and thereby reduce water waste and problems in the irrigation ponds, is a suitable solution to further reduce water waste and problems in the ponds. Figure 1 depicts some of the reservoirs for agricultural purposes such as irrigation ponds and dam reservoirs.

2.1. Properties of materials used

2.1.1. Sodium carbonate properties

The aim of the study is to add a cost-efficient mixture at the bottom of irrigation ponds in order to minimize seepage and improve water conveyance efficiency. Therefore, instead of using heavy machines to improve soil compaction, the use of sodium carbonate (scientific name: Na_2CO_3) can be recommended. The sodium carbonate properties under study is shown in Table 1.

2.1.2. Soil properties

Under our scenarios, the interaction between sodium carbonate and clay amounts in soil in terms of hydraulic conductivity was investigated and the results were compared with Equation (2). Hence, the hydraulic conductivity of each soil was measured after adding sodium carbonate at 2%, 4%, 6%, 8%, 10%, and 12% by soil weight. This research investigated the irrigation systems of north Khuzestan, including Dez and Shahur irrigation systems (Veenenbos) [27]. The prevailing soils of the north of this plain, particularly in Dez

Irrigation System region, are mostly heavy to light soil outcrops, according to library and field studies. Due to the presence of clay layers in the region, it was proposed that changes in clay content in soil should be used as the primary criterion for selecting soils. The soils were chosen as a result of multiple sampling in the field, with recorded clay rates ranging from 10% to 30%. The research agenda, which is outlined in the following sections, involved several experiments to determine the type of soil texture as well as the physical, mechanical, and chemical qualities of the soils. Cationic Exchange Capacity (C.E.C.) is an essential aspect of soils that determines its fertility potential. Table 1 shows scenarios for the prevailing soils in the areas under study. For clays and clay soils, plasticity is defined as the ability to deform without crushing the soil. The Atterberg limits refer to the moisture content of clays and silts based on their action. The Atterberg limits of the soils involved liquid limit (LL), plastic limit (PL), and shrinkage limit (SL). When fine-grained soil contains clay minerals, the soil can be formed by adding moisture without crushing. The clay particles are encased in absorbed water, which causes adhesion. In the early twentieth century, a Swedish scientist named Atterberg developed a method to describe the rigidity of fine-grained soil with different moisture contents. At very low moisture content, the soil behaves more like a solid body. At high moisture percentages, the soil and water mixture flows like a fluid.

The cation exchange capacity (C.E.C.) of soils is a significant feature that defines soil fertility potential. The cation exchange capacity of a soil is very important in terms of its physical and chemical properties, and it is used as a soil type characterization agent. According to FAO studies (Kraatz) [28], the soil texture of the studied region ranges from fat clay to loamy clay, so the hydrometry test was used to assess the soil texture. Since the amount of clay present in the final soil for testing is a criterion for selection, a hydrometer test was used to measure the texture of the soils. To conduct the research, the results of Atterberg, compaction, and hydrometry tests are summarized in Table 2. Based on these results, the textures of soil samples used in the study are loamy and silty loam.

Based on the experiments, the best soil for the mixture is one that contains at least 15% clay and has a cationic exchange capacity of 15 mEq gr per 100 gr soil. In general, the higher percentage of clay makes this mixture type practical and feasible with less problems. If the amount of sodium exchanged in clay is more than 15%, sodium ion interacts with the clay particles, causing them to diverge due to their single capacity and positive charge. The permeability of the soil is greatly reduced due to the divergence of the soil particles. This salt, by creating an alkaline environment in the soil, deactivates calcium and magnesium cations,

allowing the soil particles to stick together, and sodium is easily replaced by these cations, causing calcium and magnesium to be separated from the soil solution and bonded with CO_3 available in the soil solution and deposited in the forms of $CaCO_3$ and $MgCO_3$. The sediment remains as a solid and impermeable layer at the bottom of pond, and the sodium on the clay particles would be more durable. The soil surface, including sodium, is covered with hard skin, which prevents seed germination and thus slows or stops weed growth. Accordingly, a certain amount of sodium carbonate is added to the soil and pond bottom in such a way that the exchangeable sodium amount provides the requisite conditions for divergence. In general, adding sodium salt as much as 15% of the soil's cation exchange capacity is sufficient to disperse 100 g of soil. The following equation can be used to calculate the exact amount of sodium carbonate:

$$Na_2CO_3 = 0.055 \times \left(0.15 \times C.E.C - E.C.P\right) \tag{1}$$

Equation (1) indicates the amount of sodium carbonate needed per 100 grams of dry soil; therefore, we can use Equation (2) to measure the weight of sodium carbonate for the pond length in order to determine the geometric dimensions of the pond, the specific gravity of the soil, and the mixture thickness at the bottom of pond:

$$Na_2CO_3 = 0.055 \times P \times d \times \rho_s \times \left(0.15 \times C.E.C - E.C.P\right) \tag{2}$$

The parameters of Eqs. (1) and (2), respectively, are: Na_2CO_3: sodium carbonate amount per the pond unit length (kg), *P*: the pond wetted perimeter (m), *d:* the sidewall depth and the pond bottom to be mixed with sodium carbonate (m), ρ_s*:* the soil bulk density (g per cubic centimeter), C.E.C: Cationic Exchange Capacity (mEq gram per 100 g of dry soil), and E.S.P: Exchangeable Sodium Percentage for soil (mEq gram per 100 g of soil).

2.2. Laboratory tests

2.2.1 Permeability test

The falling head permeability test was utilized to determine the permeability of the soils in this study. This test is a laboratory technique for measuring permeability in fine-grain soils such as clays and silts that fall into intermediate and low permeability categories. An undisturbed specimen can be used in this test. In our study, water, from a standpipe that supplied water head, flowed through the specimen in the falling head test, and the water volume flowing through the soil was measured. The diameter of the standpipe was determined in desired soil. The falling head permeability test needed a falling head cell or an oedometer cell. The soil

was saturated before the flow measurements were taken, and the standpipes were filled to a certain level with de-aired water. We began the test by allowing water to flow through the soil until the water level in the standpipe fell below a certain level. Subsequently, we recorded the time required for the water in the standpipe to drop from the upper to the lower level. The standpipe was then refilled and the test was iterated several times. The recorded time should be the same for each test, within an allowable variation of about 10% (Head 1982), otherwise the test fails. It should be noted that since the soils were analyzed in a laboratory, the permeability measurements in this study would fit disturbed specimens in their saturation state. Prior to the start of the experiment, all soils were immersed in water for 24 hours to ensure that they were fully saturated. The test started after the soil was fully saturated and the system was de-aerated. Equation (3) can be used to measure the permeability coefficient by recording water level values in a burette over time.

$$K = \frac{aL}{At} 2.303\ Ln \frac{h_1}{h_2} \tag{3}$$

where a is burette cross section area, L is soil length, A is soil cross section area, t is the elapsed time per second, h_1 is the water head on the soil at time t=0 in cm, and h_2 is water head on the soil at time t=T in cm. Figure 2 shows an overview of the falling head device. It should be noted that the results presented in the tables and graphs are based on the average results of the test three times for each mixture in each step.

2.2.2. Microstructural test

SEM was used to evaluate the structural effect of mixing soil with sodium carbonate. SEM (Scanning Electron Microscopy) is a test method that uses an electron beam to scan a sample and produce a magnified image for analysis. SEM analysis, also known as SEM microscopy, is a technique for microanalysis and failure analysis of solid inorganic materials that is very effective.

2.2.3. pH test

The pH of soil is a measurement of its acidity or alkalinity. Because pH is measured on a logarithmic scale, a reduction in pH equals a tenfold rise in acidity, so even tiny changes in pH values can have significant implications. The ASTM D4972 standard is used to conduct the soil pH test.

2.2.4. Compaction test

Soil compaction is a process in which a soil is subjected to mechanical stress and densification. Soil is made up of solid particles and voids filled up with water and/or air. Soil as a three-phase system provides a more extensive explanation of soil's three-phase nature. When stressed, soil particles are redistributed inside the soil mass. Therefore, the volume of voids in the soil is reduced, which leads to the soil densification. Kneading, as well as dynamic and static methods, can be used to apply mechanical stress. The change in the dry unit weight of the soil, γ_d, is used to determine the degree of compaction. Compaction is particularly beneficial in engineering applications since it causes: a) soil strength to increase, b) soil compressibility to decrease, and c) soil permeability to decrease. In structural and engineering applications such as embankments, earth dams, foundation support and pavement support, these elements are critical. Compaction degree is determined by soil characteristics, the type and amount of energy delivered by the compaction process, and the water content of the soil. There is an optimal amount of moisture for each soil at which it can meet maximum compaction. In other words, a soil reaches its maximum dry unit weight $\gamma_{d(max)}$ at an optimum water content level ω_{opt} for a given compactive effort.

3. Results and discussion

3.1. Test results of soil samples

In order to calculate the amount of sodium carbonate that needs to be mixed with soil at the bottom of the pond, the soil samples were sent to a laboratory to have their physical and chemical properties determined. The results of physical and chemical tests of the soils are shown in tables 3, 4, and 5.

3.2. Test results of SEM

SEM analysis was used to explore the textures of soils with and without sodium carbonate. Figure 3 shows four SEM images of soils sample No.3 (silty loam with 10% clay) before mixing with dispersants and soil mixed with 10% sodium carbonate after one, three and seven days of curing, respectively. Figure 3 shows that the reactions have not yet taken place well in the soil sample mixed with sodium carbonate after one day of curing (Figure 3-b), and that the reactions have taken place well in the soil sample mixed with sodium carbonate after three days of curing (Figure 3-c), and that a fine texture has been produced due to soil dispersion and reduction of voids in the soil after seven days of curing (Figure 3-d), indicating a decrease in soil permeability.

3.3. Test results of permeability

In this study, the permeability coefficient was measured after the saturation using the falling head method for the mixture (soil and sodium carbonate). The water amount extracted from each soil was recorded over a period of 20 minutes in each step. The results are shown in Figures 4, 5 and 6. Since the soils were dispersed by adding 12% sodium carbonate, the experiments results are shown up to 10%.

Figures 4, 5, and 6 show that the volumetric changes versus time have a steep gradient at first, but then the curves gradient becomes almost constant after a while. And this demonstrates how the water flow in the soils gradually shifts from laminar to turbulent. The water flow is laminar at first in a steep gradient, then transitions to a transition flow, and eventually converts to a turbulent flow in a nearly constant gradient. As shown in Figures 4, 5, and 6, the highest permeability reduction value, calculated in the three soil samples, is in 10% sodium carbonate. Based on the results, a suitable soil for layering contains at least 15% clay and has a cation exchange capacity of 15 mEq gram per 100 g soil, whereas the first soil, which has a Si-L soil texture, contains only 10% clay. However, the results showed that the soils with clay content of up to 10% can be used as a good option for using sodium carbonate to minimize the seepage. Figures 4 through 6 illustrate the volumetric changes and indicate the accuracy of the test results as well as their stability during a 20-minute experiment. The permeability coefficient was then calculated using the Darcy equation. The permeability results for the soils in Table 6 were calculated using Eq. 3 and are shown below.

The hydraulic conductivity coefficient of all the three soil samples decreases as the sodium carbonate percentage increases, as seen in Tables 6 and 7. This demonstrates that adding sodium carbonate to soils lowers their permeability coefficients, resulting in less seepage. Table 7 shows the percentages of the permeability reductions in the soils. As the sodium carbonate percentage increases, the hydraulic conductivity coefficient of all the three soil samples decreases. The values in Table 7 demonstrate that soil sample #1 (loam with 20% clay), soil sample #2 (loam with 15% clay), and soil sample #3 (silty loam with 10% clay) reduce hydraulic conductivity coefficient up to 41.79%, 64.43% and 71.51% at 10% sodium carbonate, respectively. As can be seen, the maximum decrease of the permeability coefficient in the soils occurs in the 10% sodium carbonate and the maximum decrease in the permeability coefficient occurs in soil sample #3 (silty loam with 10% clay) with 71.51%, indicating that sodium carbonate performs better in soil

sample #3 (silty loam with 10% clay). Triangular graphs in Figure 7 depict the permeability contours for different percentages of sodium carbonate mixed with all soil samples.

As in tables 6 and 7, the graphs shown in Figure 7 also indicate that soils permeability decreases as the sodium carbonate percentage increases. As shown in Figures 7(a) to 7(f), the area of the graphs with a zero-permeability coefficient (permeability in the vertical direction) increases with a constant trend; that is, the use of sodium carbonate causes more vertical permeability of more soil types to be zero or, more generally, the permeability of more soil types is decreased.

The contour lines show that soils with more sand and silt have more permeability (approached contour lines with more permeability values in the up and down-right corners and close to the right border of figures) and soils with more clay have less permeability (distanced contour lines with less permeability values in down-left corner of figures). In reality, the figures show a nearly identical pattern of permeability reduction. However, in Figures 7(a) to 7(e), the maximum permeability values occur in the up and down-right corners of the figures and close to the right border of the figures. In Figure 7(f), the maximum permeability values occur in the middle of the up and down-right corners and a little far from the right border of the figure. The contours form is almost identical in Figures 7(a) to 7(f); however, the contours form in Figure 7(f) is different from the other figures. The contour lines are close to the right border of Figures 7(a) to 7(f) between up and down-right corners, whereas the contour lines, in Figure 7(f), tend upwards in up corner between the right and left borders.

3.4. Test results of compaction

Proctor compaction test, based on the standard ASTM D698, carried out for all the three soil samples in different percentages of sodium carbonate. The maximum increase in maximum dry specific weight of soil samples occurred when 10% sodium carbonate was added to the soil samples, as shown in Figure 8, resulting in the maximum compaction in these conditions and maximum permeability decrease as a consequence.

3.5. Test results of pH

The pH of soil samples (without sodium carbonate) was practically neutral, according to pH testing, and when sodium carbonate is added to soil samples, the pH rises to a maximum of 10.8 over time. As a result of the addition of sodium carbonate to the soil, it becomes alkaline. Soil permeability is reduced by alkalinity of more than 9 in soils combined with sodium carbonate. According to Figure 9, the maximum pH levels for all

the three soil samples are around 10% sodium carbonate, depending on temporal fluctuations. The following is a description of soil alkalinization caused by the reaction of sodium carbonate with water added to soil samples. In water, sodium carbonate decomposes into two sodium cations ($2Na^+$) and one carbonate anion (CO_3^{2-}). The reaction of Na_2CO_3 with H_2O is as follows:

$$Na_2CO_3 + H_2O \Rightarrow 2Na^+ + CO_3^{2-} + 2H^+ + 2OH^- \quad (4)$$

As a result of the reaction (4), the following will occur.

$$Na_2CO_3 + H_2O \Rightarrow 2Na^+ + 2OH^- + H_2CO_3 \quad (5)$$

Soil alkalinity is caused by sodium hydroxide ($NaOH$).

4. Comparison of the optimum situation

Figure 10 shows radar diagram of the interaction of maximum dry specific weight of soil prototypes, maximum dry specific weight of soil mixed with 10% sodium carbonate, optimum moisture content of soil prototype, balanced pH of soil mixture and sodium carbonate after about 10 days from mixing samples with 10% sodium carbonate versus permeability. According to the radar diagram, samples with more clay have a higher maximum specific gravity of dry soil, indicating higher compaction and, as a result, less permeability. But sodium carbonate, for samples with less clay, has the maximum effect on seepage reduction. This means that the lower the percentage of clay in the sample and the lower the percentage of sand, the better the material dispersers' chances of reducing water seepage from the bottom of water storage ponds.

6. Application in Practice

The use of dispersants to reduce water seepage from the bottom of earthen water storage ponds has shown that the soil must contain at least 10% clay. To use sodium carbonate to reduce water seepage from the bottom of earthen ponds, take the following steps:

- First, any vegetation, wood, stone, or other debris must be removed from the pond's bottom. Then, to a depth of about 20 cm, dig the pond's bottom and store the soil near the pond.
- Then, up to a depth of 10 cm, turn the soil of the pond's bottom, removing any roots, plants, wood, or stones.
- Compact the bottom layer of the pond at optimum moisture.
- A layer of excavated soil about 10 cm thick should be spread on the pond's bottom.
- Sodium carbonate can be spread dry on the soil surface or mixed with water and sprayed on it.

- After that, sodium carbonate should be mixed with a disc or cultivator and compacted to optimum moisture, and then it should be cured for a week.
- The last layer of soil should be spread on the pond's bottom and compacted at optimum moisture.
- A smooth drum roller or pneumatic tire roller should be used to compact a soil final layer (without sodium carbonate) as a lining for preventing from alkalinization of water in the irrigation pond.
- It is recommended that the pond's bottom be protected from erosion at the inlet of the water flow.

5. Conclusion

According to the results, when 10% sodium carbonate was mixed with soil samples, hydraulic conductivity coefficients in soil sample #1 (loam with 20% clay), soil sample #2 (loam with 15% clay), and soil sample #3 (silty loam with 10% clay) decreased by 41.79, 64.43, and 71.51%, respectively. It was observed that the maximum decrease of the permeability coefficient in the soils occurred in the 10% sodium carbonate and the maximum decrease in the permeability coefficient was in the soil sample #3 (silty loam with 10% clay) with 71.51%, indicating that sodium carbonate had the best performance in soil sample #3 (silty loam with 10% clay) and can thus increase the cultivation area in regions with water shortages. The SEM analysis demonstrated that after 7 days of curing, the soil texture became finer, leading to a reduction in soil voids and finally in soil permeability. According to pH test results, the addition of sodium carbonate raised soil alkalinity, which reduced soil permeability. When sodium carbonate was added to the soil, soil compaction was increased, hence decreasing soil permeability, according to compaction test results. Overall, the results indicate that using a pond sealer to prevent seepage at the bottom of an irrigation pond is a viable option for minimizing seepage in this type of pond. As a result, the permeability coefficient drops dramatically, resulting in finer soil texture due to decreased porosity.

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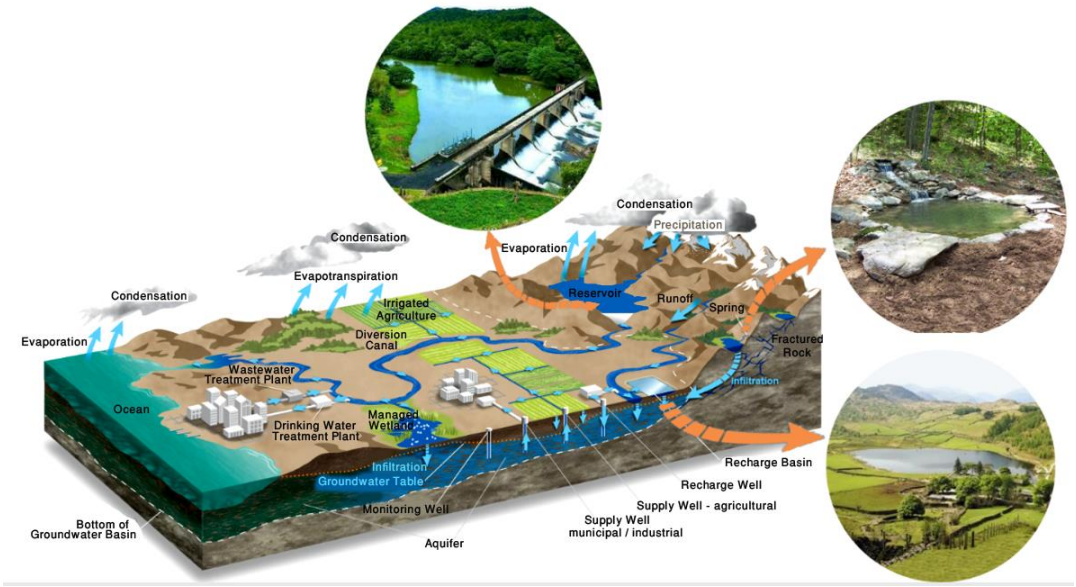


Figure 1. Some of the reservoirs for agricultural purposes such as irrigation ponds and dam reservoirs.

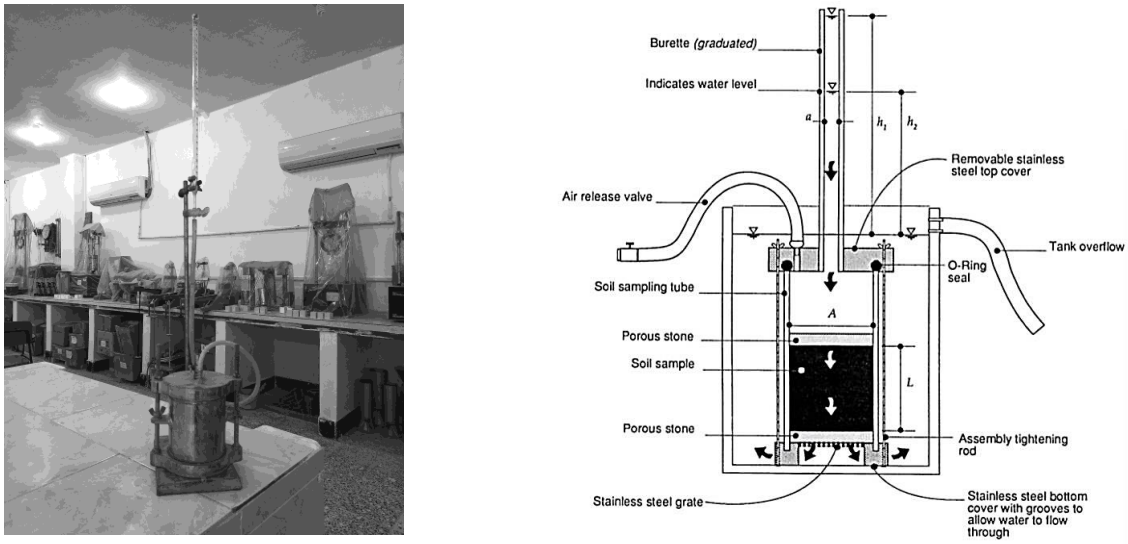
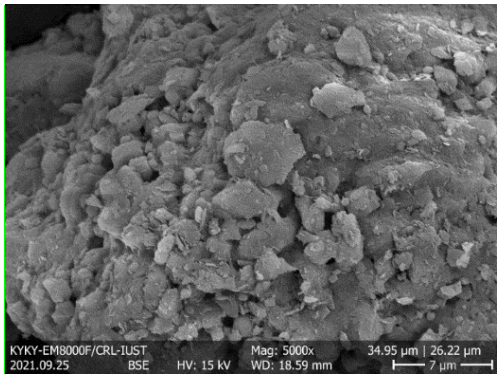
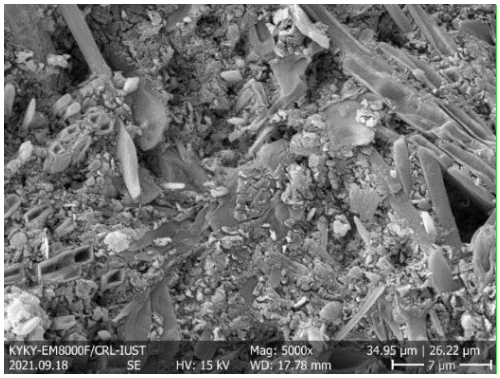


Figure 2. The falling head device in Soil Mechanics Lab and its schematics

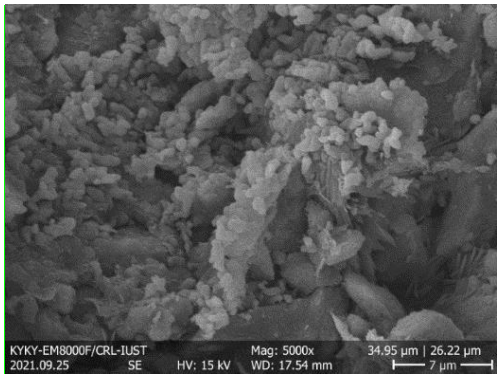


a) Soil structure before adding sodium carbonate



b) Soil structure after one day of adding 10% by

weight of sodium carbonate



c) Soil structure after three days of adding 10% by weight of sodium carbonate

d) Soil structure after seven days of adding 10% by weight of sodium carbonate

Figure 3. Comparison of soil texture for a soil without sodium carbonate and the same soil with sodium carbonate 10% after one, three, and seven days

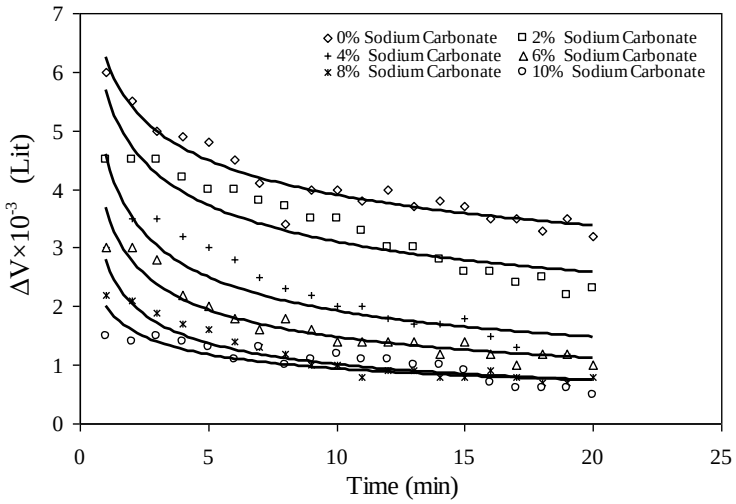


Figure 4. Temporal changes in the amount of water released in soil sample #1 (loam with 20% clay)

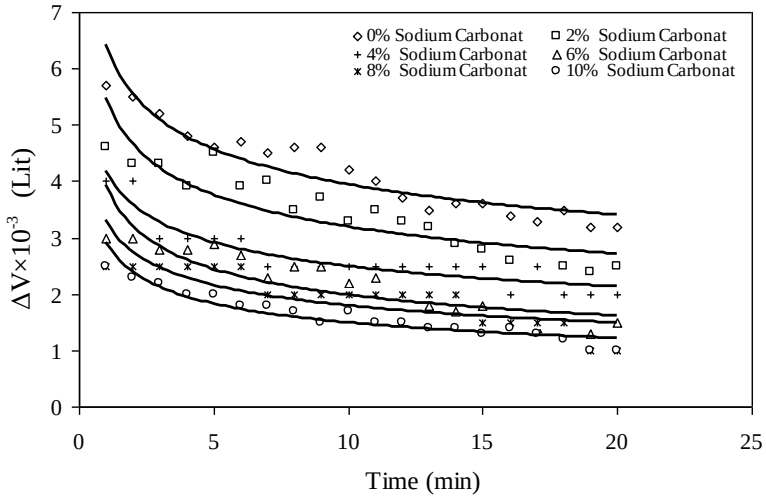


Figure 5. Temporal changes in the amount of water released in soil sample #2 (loam with 15% clay)

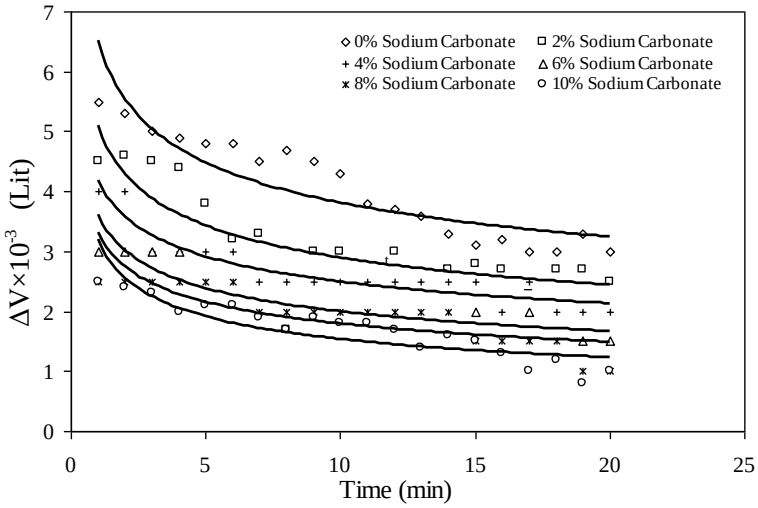
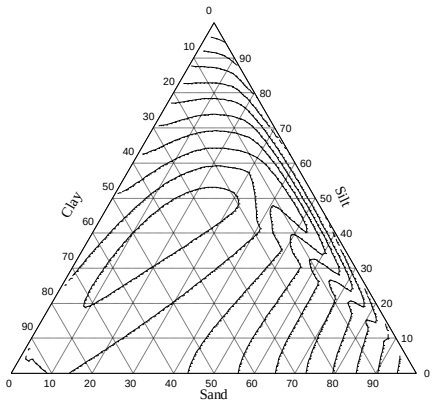
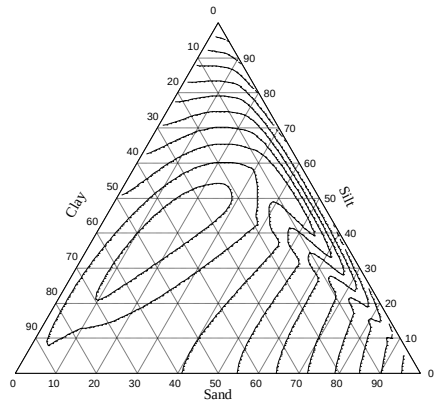


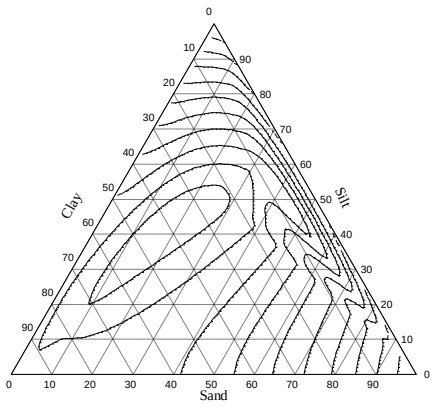
Figure 6. Temporal changes in the amount of water released in soil sample #3 (silty loam with 10% clay)



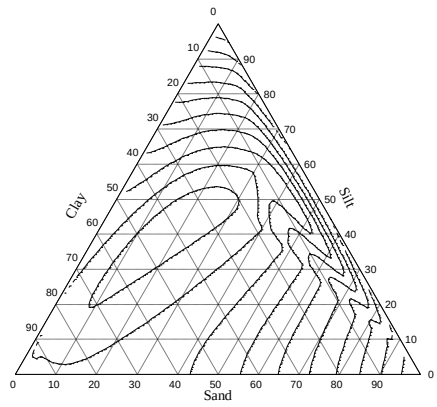
(a)



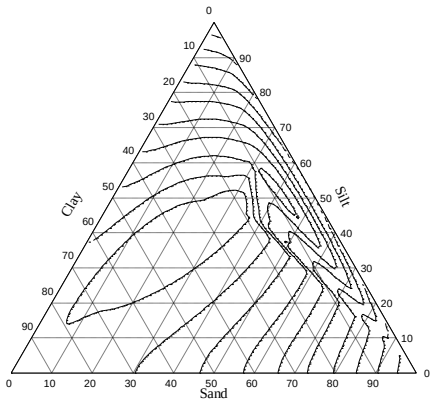
(b)



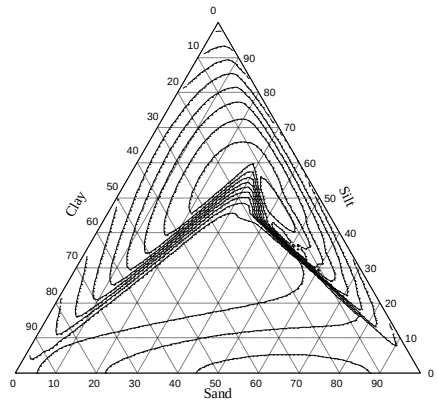
(c)



(d)



(e)



(f)

Figure 7. The permeability contour line in soil samples mixed with various percentages of sodium carbonate, a) 0%, b) 2%, c) 4%, d) 6%, e) 8%, f) 10%

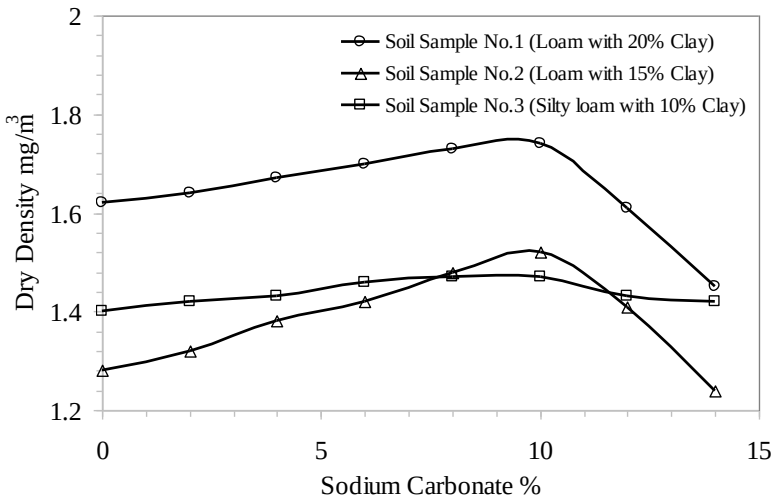


Figure 8. Maximum dry specific weight versus sodium carbonate percentages

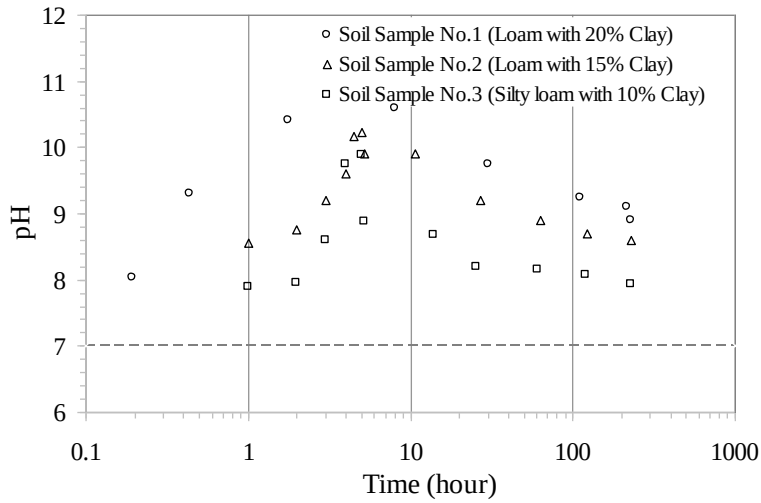


Figure 9. Summary of the effect of soil samples mixed with 10% by weight of sodium carbonate in pH test

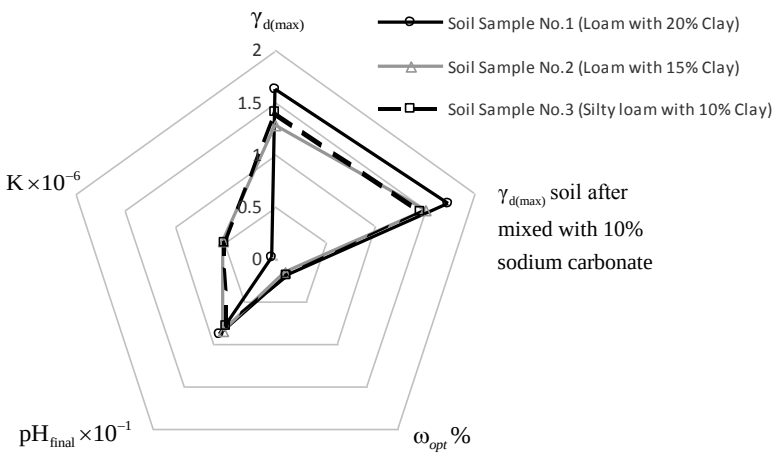


Figure 10. Radar diagram of the interaction of effective parameters in the study

Table 1: The sodium carbonate properties used for study – Na_2CO_3

Na_2CO_3	Sodium Carbonate
Molecular Weight/ Molar Mass	106 g/mol
Density	2.54 g/cm³
Boiling Point	1,600 °C
Melting Point	851 °C
Appearance	White Power

Table 2. The soil samples used in the design

Properties	Atterberg limits	USCS Classification*	Compaction Properties	Soil Texture

		Liquid Limit	Plastic Limit	Plasticity Index		$\gamma_{d(max)}$ gr/cm^3	ω_{opt}%	Type of Soil Texture	Sand %	Silt %	Clay %
Sample No. 1	Not Dried	22.40	19.10	3.30	ML	1.50	22.40	L	34	46	20
	Dried	22.63	18.52	4.10		1.62	18.50				
Sample No. 2	Not Dried	18.64	16.25	2.40	ML	1.38	16.30	L	40	45	15
	Dried	17.68	16.40	1.30		1.28	16.40				
Sample No. 3	Not Dried	18.40	16.80	1.60	ML	1.46	17.80	Si.L	28	62	10
	Dried	19.05	17.57	1.50		1.40	18.60				

*Unified Soil Classification System

Table 3. The chemical test results of soil samples

Soil Sample	Conductivity Coefficient	PH	Saturation Percentage	Total Nitrogen	Organic carbon percentage	Sodium absorption ratio	Soil exchangeable soil	Cation exchange capacity
No.1	0.35	7.60	40.00	320	0.05	0.72	1.30	11.00
No.2	0.85	7.50	33.40	850	0.21	1.80	0.44	11.00
No.3	1.60	7.50	36.70	350	0.24	2.20	0.42	10.50

Table 4. The anions analysis of the soil samples

Soil Sample	Sulfate mg/liter	Chlorine mg/liter	Bicarbonate mg/liter	Total anions mEq gram/liter
No.1	55.00	35.50	120.00	4.20
No.2	4.50	2.00	2.00	0.17
No.3	8.00	5.00	4.00	0.38

Table 5. The cations analysis of the soil samples

Soil Sample	Potassium mg/liter	magnesium mg/liter	Calcium mg/liter	Sodium mg/liter	Total Cations mEq gram/liter
No.1	2.50	10.00	40.00	20.00	3.70

No.2	-	2.80	3.20	3.00	0.52
No.3	-	5.60	6.40	5.50	1.03

Table 6. The values of the hydraulic conductivity coefficient for soil samples mixed with sodium carbonate

Sodium carbonate percentage	**Permeability in the soils ($\times 10^{-7}$ cm/s)**		
	Soil sample contains 20% clay	**Soil sample contains 15% clay**	**Soil sample contains 10% clay**
0	0.067	1.490	1.790
2	0.056	1.270	1.030
4	0.053	0.990	0.840
6	0.048	0.720	0.660
8	0.041	0.630	0.570
10	0.039	0.530	0.510

Table 7. The permeability decreases changes of the soil samples in percentages.

Sodium carbonate percentage	**Permeability decrease changes in the soils (%)**					
	Soil sample contains 20% clay		**Soil sample contains 15% clay**		**Soil sample contains 10% clay**	
	Compared to the previous	**Compared to the first**	**Compared to the previous**	**Compared to the first**	**Compared to the previous**	**Compared to the first**
0	0	0	0	0	0	0
2	16.41	16.41	14.76	14.76	42.46	42.46
4	5.36	20.90	22.05	33.56	18.45	53.07
6	9.43	28.36	27.27	51.68	21.43	63.13
8	14.58	38.80	12.5	57.72	13.64	68.16
10	4.88	41.79	15.87	64.43	10.52	71.51

Biography

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