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# Geotechnical Properties of the Soil Contaminated with Medical Waste: a Case Study of Metronidazole and Amoxicillin Waste

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## ABSTRACT

Soil contamination with medicines can occur when unused or expired medications are improperly disposed of or when pharmaceutical manufacturing waste is inadequately treated or managed. Moreover, the largest percentage of damaged and expired medical materials in the sanitary landfill area during the COVID-19 period in the study region were Metronidazole (Flagyl) and Amoxicillin. The disposal of numerous drugs and medical waste from Al-Jazeera Pharmaceuticals Company, which were examined and found to have a higher concentration of the compound Metronidazole (Flagyl) and Amoxicillin, This study aimed to analyze the results of the impact of Metronidazole (Flagyl) and Amoxicillin concentrations on the chemical and geotechnical properties of soil. Undisturbed soil samples was collected and then cured by mixing 10 mg/l of Metronidazole (Flagyl) and 25 mg/l of Amoxicillin to the time period from 15 to 135 days. The obtained geotechnical tests results of natural and contaminated silty clay soil showed that the soil became softer, the cohesiveness between the particle sizes of soil decreased due to the absorption of the soil by the Metronidazole (Flagyl) and Amoxicillin concentration. Moreover, the results indicate that the soil collapse rose from 5.6 to 9.5 after 150 days of curing.

**Keywords:** clay soil, soil pollution, collapse, Metronidazole, Amoxicillin.

## INTRODUCTION

In recent decades, both the manufacturing and use of pharmaceutical products have rapidly increased with the advancement of medical treatment. Roughly 3,000 pounds are used as pharmaceuticals, and the annual production quantity exceeds dozens of tons (Carvalho & Santos, 2016). Prevention is key to reducing environmental medicine waste. These aromatic molecules degrade slowly, leaving them in the environment. Alternatives include disease prevention, personalized treatment, pack size optimization, and pharmaceutical redistribution marketplaces (Kusturica et al., 2022). Until recently, pharmaceutical manufacturing was generally seen as a no-brainer, contributing to environmental pollution on the one hand, and not forming any environmental danger from it consequence on the other hand (Babatunde et al., 2014). However, recent findings suggest the opposite: some manufacturing facilities around the world have been identified to discharge them into the environment, exceeding the previously defined levels, causing contamination (Nijsingh et al., 2019). These wastes are either disposed of in the soil or spilled with some waste on the soil, and as a result of leaching, they enter the soil. In the last decay, many studies were performed to correlate the mechanical properties with the physical properties (Surendra, 2022). Many studies have been carried out on the effects of pollutants on soil, including the research by (Chae & An, 2018). The effects of sewage on soil using mixed and non-mixed models on the mechanical and physical properties of soil showed a considerable rise in the plastic index, unrestricted pressure, and cutting transactions (Urbaniak, 2017; Kadhim et al., 2023). Undisturbed models were used and contaminated with tetracycline pharmacological residues to study physical and mechanical properties. The study found that the unconfined pressure was reduced by up to six months, while the impact on the Atterberg boundary showed that the soil was becoming softer, resulting in a decreased liquid limit. The testing of tetracycline in leachate decreased over time. This approach was adopted to save time and reduce the cost of site investigations. In addition, to appoint a preliminary foundation design before performing detailed site investigations. This approach was adopted from the earlier researcher in the field of soil mechanics and foundation engineering, some of these correlations are listed in the studies by (Look, 2014). The influences of wastes on soil depend on type of soil and nature of wastes. Undisturbed models contaminated with tetracycline pharmacological residues were used to study physical and mechanical properties.The the differences in the geotechnical properties of the soil due to the disposal of industrial waste, variations in geotechnical properties of soil due to disposal of industrial wastes have been discussed (Surendra, 2022). The objective of this study was to assess the specific impact of Metronidazole (Flagyl) and Amoxicillin drug manufacturing waste on soil geotechnical properties. By conducting laboratory tests and analyses on undisturbed soil, the study aimed to identify any changes in soil characteristics, such as liquidity and plastic limits, strength, and cohesion. The motivations to study the soil contamination with medicines can be listed as follows:

1. Leaching and runoff: Medicines that are disposed of inappropriately, such as flushing them down the toilet or pouring them down the sink, can enter the wastewater system.
2. Ecological effects: Soil contamination with medicines can have adverse effects on soil organisms, including microorganisms, insects, and plants.
3. Groundwater contamination: Pharmaceuticals that enter the soil have the potential to percolate through the soil layers and reach groundwater reservoirs. Groundwater serves as a vital source of drinking water for many communities. The presence of pharmaceutical compounds in groundwater can raise concerns about the safety and quality of the water supply.
4. Resistance development: Exposure of soil microorganisms to low levels of pharmaceuticals can contribute to the development of antibiotic resistance. The presence of antibiotics in the soil creates selective pressure that favors the survival of resistant bacteria, which can subsequently spread to human and animal populations.

## MATERIAL AND TECHNIQUES

### Soil

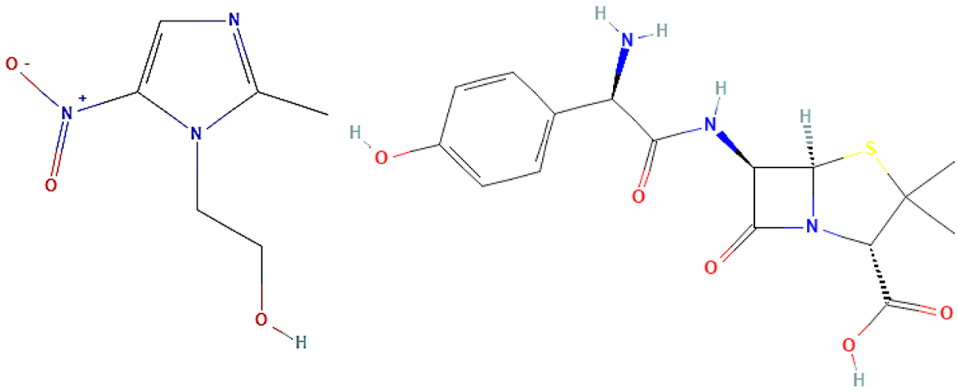
Undisturbed soil of 10 samples were taken from a depth of 1.0–1.5 meter below the natural ground level. The soil description is medium to stiff brown silty Clay. The basic soil properties are: Dry density 00.00 g/cm$^3$, initial water content 20%, specific gravity 2.64, Liquid and plastic limits 26% and 21% respectively.

### Medical waste additive

Two types of medicines were used as medical waste additives, brought from the Al-Jazeera Company located in the Abu Ghraib region west of Baghdad, these are Metronidazole (Flagyl) and Amoxicillin. The reasons behind the selection of these materials are the analysis of the concentration of the sewage water of the medicine factory is rich with the Metronidazole (Flagyl) and Amoxicillin medicine. Moreover, the largest percentage of damaged and expired medical materials in the sanitary landfill area during the COVID-19 period in the study region were Metronidazole (Flagyl) and Amoxicillin. The Molecular Formula of Metronidazole (Flagyl) and Amoxicillin Drugs are $C_6H_9N_3O_3$ and $C_{16}H_{19}N_3O_5S$, respectively. the molecular weight of Metronidazole (Flagyl) and Amoxicillin drugs are 171.15 g/mol and 365.4 g/mol, respectively (Uthansingh et al., 2021). The structure of the two drugs is shown in Figures 1 and 2. The concentration of the medicines solution consist of 10 mg/l of Metronidazole (Flagyl) and 25 mg/l of Amoxicillin. The chemical analysis is carried out using High Performance Liquid Chromatographic (RP-HPLC), column Inertsil ODS C18 column (250X4.6 mm×5μ). The detection wavelength for Metronidazole (Flagyl) was set at 271 nm, and 230 nm for Amoxicillin.

## EXPERIMENTAL WORK

The experimental work of this study can be summarized as follows:



(a) (b)

**Figure 1.** Chemical structure depiction: (a) Metronidazole (Flagyl), (b) Amoxicillin (NIH National Library of Medicine NCBI, 2023)

- Extraction of soil samples and bringing them to the laboratory for testing.
- Preparation of medicine waste additives. The concentration of the medicines solution consist of 10 mg/l of Metronidazole and 25 mg/l of Amoxicillin.
- In order to simulate the environmental pollution occurring in the study area due to the medical waste, soil samples were exposed to a solution of the Metronidazole -Amoxicillin with the same time periods of pollution that were occurring on the ground. The first soil sample was tested in its natural condition without pollution. The curing interval for the 9 soil samples was cumulative, starting from 15 days for the second sample and ending with 135 days for the tenth sample. The Metronidazole -Amoxicillin solution was added to the soil sample by daily fill out the upper part of the Shelby tube with this solution.
- After the end of each curing period, the soil sample was extruded from the Shelby tube and prepared for further geotechnical tests.
- The chemical tests of the soil samples after contaminated with Metronidazole-Amoxicillin solution are: pH, carbonate ($CO_3$), electrical conductivity (EC), sulfates ($SO_3$) and ($SO_4$), total soluble salts (TSS), chloride (Cl) and organic matter (OM).
- The geotechnical tests of soil are water content, hydrometer, specific gravity and consolidation tests. This process was shown in Figure 2.

## RESULTS AND DISCUSSION

### Chemical tests

The results of the chemical tests are presented in Figures 3 to 10. In Figure 3, it is observed that the additive initially increased the a

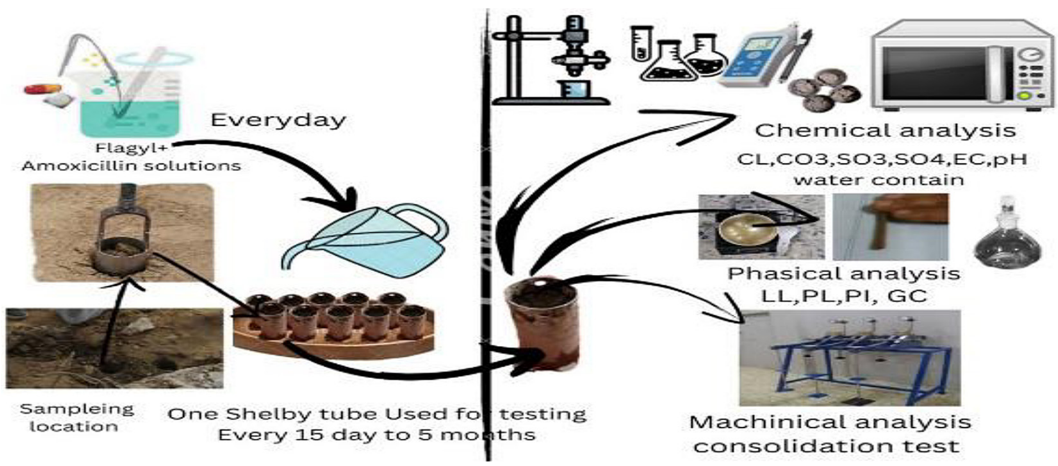



**Figure 2.** Work process step

pH value to about 9. Then, the pH value started to decrease gradually, making the soil less basic and closer to neutrality due to the degradation of organic matter over time, despite its slow degradation and the presence of amino acids due to a significant presence of bicarbonate ions in this soil. These results are confirmed with limitation indicated by (Neina, 2019).

In Figure 4, the carbonate ($CO_3$) sharply decreased over time until it reached the minimum level and/or vanished after about four months from beginning of the contaminated stage. This behavior can be related to the physiochemical action of salt bonds between soil grains due to dissolving and remove out the soil structure. This results are also confirmed with the results obtained by (Shiva Shayegan Salek Ozge Bozkurt Andre van Turnhout, 2016).

In Figures 5 and 8, it is evident that the amount of Electrical conductivity (Ec) and Total soluble salts (TSS) are significantly increased, ranging from 675 to 2880 (mS/m) for Ec and 0.2 to 10% for TSS, respectively, due to the addition of medicine solution and causes the rising in sulfur, chloride contents over time. The concentrations of chlorates and sulfates ($SO_3$ and $SO_4$) were illustrated in Figures 7, 8, and 9, respectively. These concentrations showed an initial increase over the first months, followed by a subsequent decline at a small rate in recent months, ranging from 0.08% to 0.21%, 9–12.7%, and 10.4–12.7%, respectively. This variation can be attributed to factors such as saturation, laudation, and chemical reactions of the elements.

Figure 10 shows the relationship between the organic content (OM) and time. This relation indicated that a reduction in OM with the time. This is due to the fact that these organic aromatic drugs are long and difficult to decompose by bacteria. As a result, a fraction of them may remain solid, interacting with the soil and becoming solid, organic aromatic drugs that is part of aromatic compounds. Carpio et al. (2021) explained that aromatic compounds are among the most prevalent and persistent pollutants in the environment, while another portion is retained between soil particles or exits with soil filters. Some of the medicine pills may also run between soil particles and emerge from the soil. Nyambara Ngugi et al. (2019) noted that organic compounds that would otherwise be easily degradable may resist degradation if they are absorbed by surfaces or surrounded by innate organic materials.

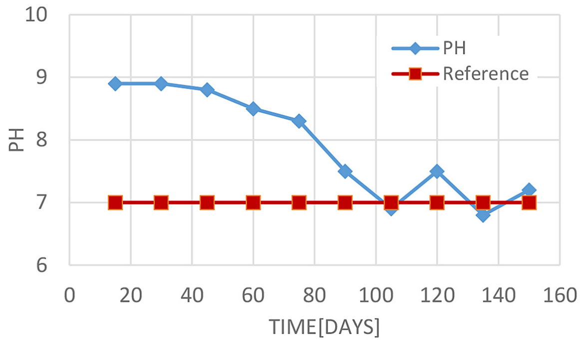



**Figure 3.** pH – time relationship

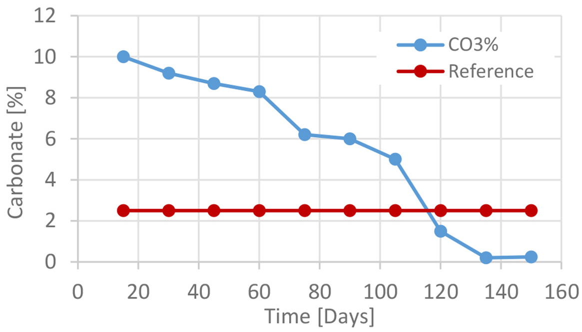



**Figure 4.** Carbonate – time relationship

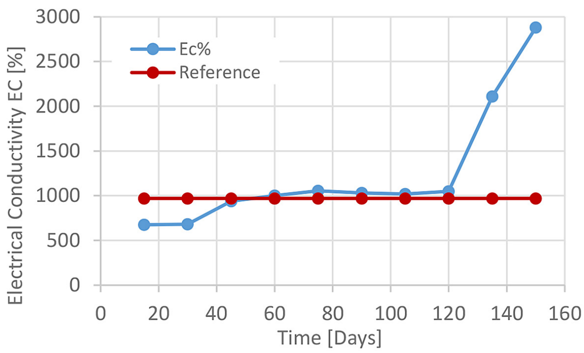



**Figure 5.** Electrical conductivity – time relationship

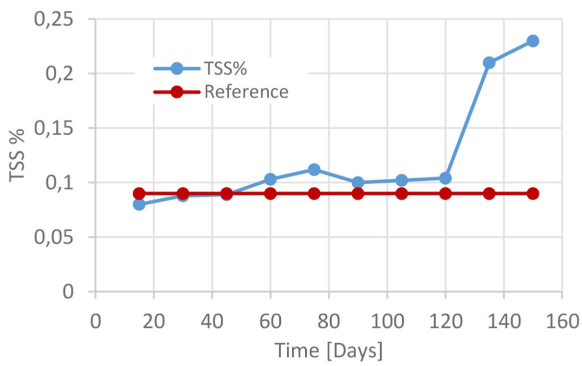



**Figure 6.** TSS – time relationship

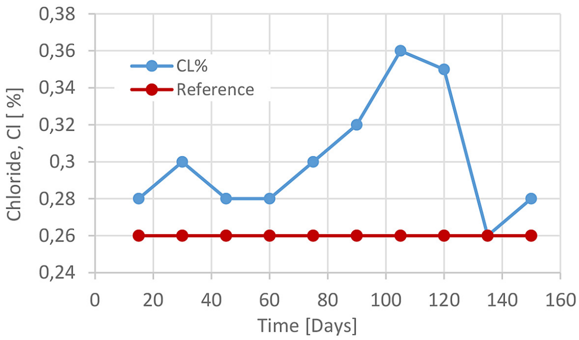



**Figure 7.** Chloride – time relationship

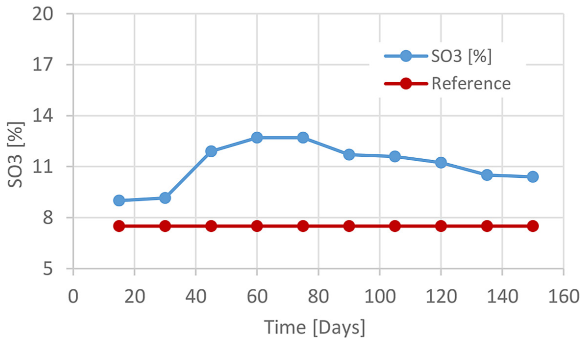



**Figure 8.** $SO_3$ – time relationship

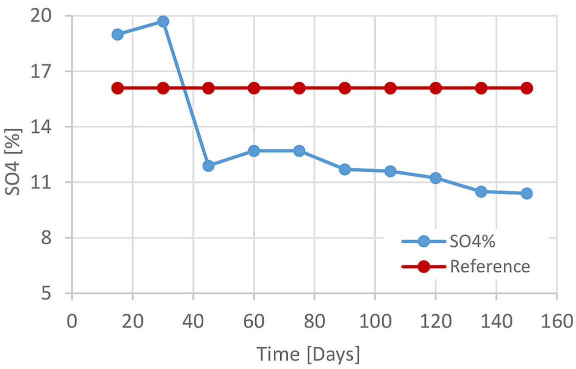



**Figure 9.** $SO_4$ – time relationship

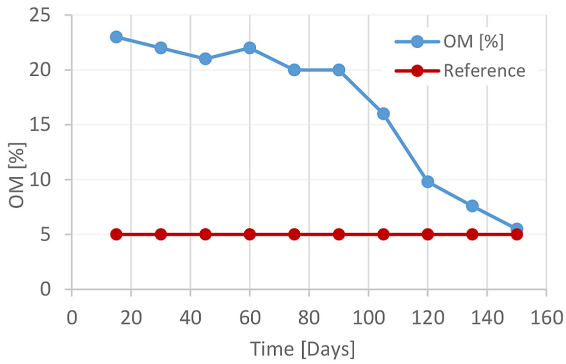



**Figure 10.** Organic matter – time relationship

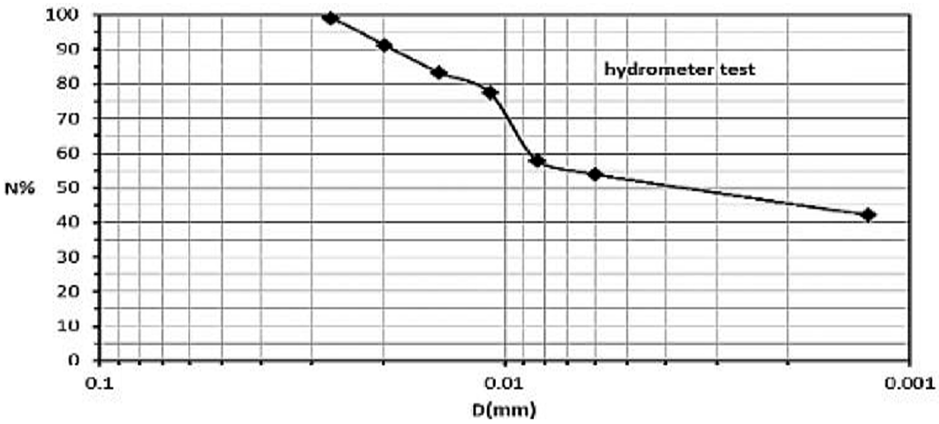



**Figure 11**. Hydrometer test

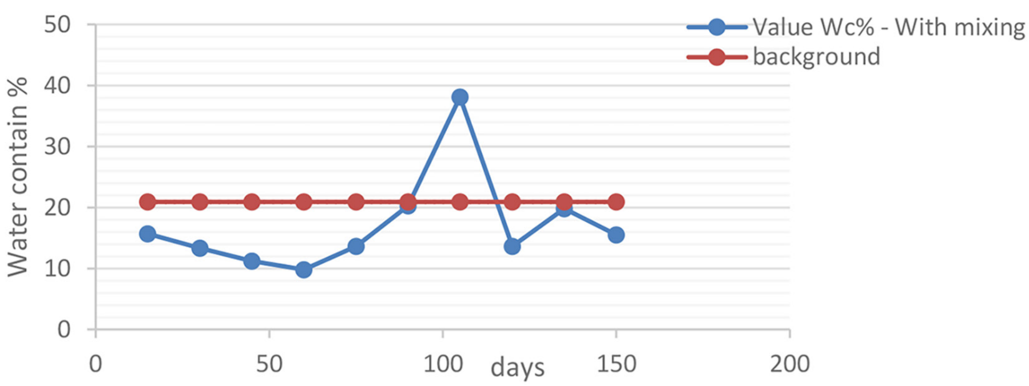



**Figure 12.** Water content – time

## Geotechnical tests

### *Soil classification*

The soil classification is carried out according to Unified Soil Classification System (Amuda, 2014). The natural soil can be classified as silty Clay (Cm) soil. The hydrometer test was shown in Figure 11.

### *Water content*

The addition of Metronidazole-Amoxicillin to the soil, combined with mixing, initially caused a decrease in water content. However, after 75 days, the water content unexpectedly increased. This could be due to various factors, such as the absorption capacity of the substances or the interaction with soil particles. After 105 days, there was a significant increase in water content, suggesting a potential change in the hydraulic properties of soil. The subsequent fluctuations in water content indicate a complex and dynamic interaction between the added substances and the soil over the experimental period. The W.C exceed the limits, at excessive humidity (more than 20% to 38%), some problems may occur that may affect the performance of the foundation, the high moisture content may cause the soil to sag at it dries out, leading to cracks in the foundation (Kuan Zhang et al., 2023). The relation between water contain and time was shown in Figure 12.

**Table 1.** Severity of soil sample according to collapse potential (CP)

| Type collapse severity of problem according to [21] | Collapse potential (CP) | Curing time (days) |
|---|---|---|
| Trouble | 5.6 | 1 |
| Moderate trouble | 1.3 | 15 |
| Moderate trouble | 1.7 | 30 |
| Moderate Trouble | 3.1 | 45 |
| Trouble | 8 | 60 |
| Trouble | 6.7 | 75 |
| Trouble | 7.2 | 90 |
| Trouble | 7.8 | 105 |
| Trouble | 9 | 120 |
| Trouble | 8 | 135 |
| Trouble | 9.5 | 150 |

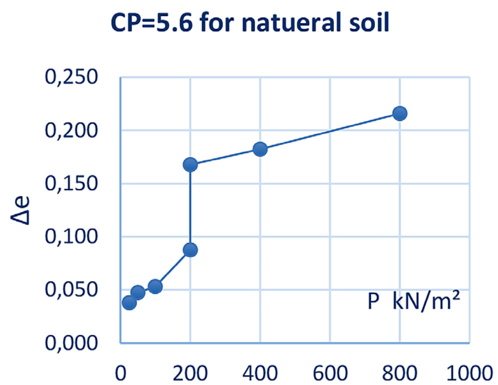


**Figure 13**. CP for natural soil

### *Collapse test*

In order to impacts of integrating pharmaceutical waste into clay soil, a systematic introduction of pharmaceutical waste was conducted at regular intervals of 15 days, and the subsequent levels of absorption were monitored for a duration of 150 days. The data supplied illustrates the observed consequences, where the levels of assimilation are found to fall within the prescribed ranges. The collapsed sample is then exposed to extra pressure to form the submerged pressure curve. The quantity of soil layer collapse is simply derived from Figure 12 between the changes of void ratio with load pressure.

Table 1 provides an indication of the potential severity of collapse with the data of value of collapse during time curing. During the initial day of the experiment, the soil was initially assessed

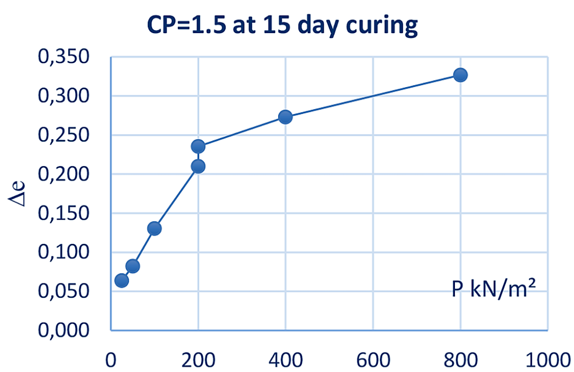


**Figure 14.** CP at 15th day curing

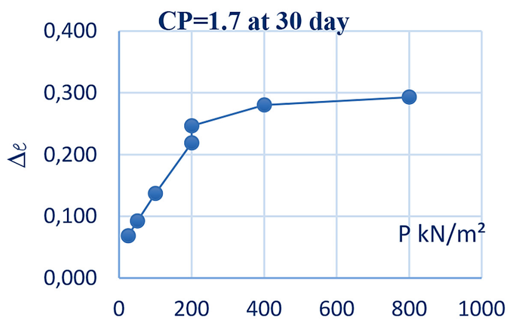


**Figure 15**. CP at 30th day curing

without the inclusion of any waste materials. The research revealed an initial assimilation level of 5.6, as depicted in Figure 13.

According to the findings shown in Figure 14, there was a decrease in the degree of absorption to 1.5 on the fifteenth day of continuous introduction of pharmaceutical waste. On the thirtieth day, a slight elevation in the level of assimilation was observed, reaching a value of 1.7, as depicted in Figure 15. On the 45th day, there was an observed further increase in value to 3.1, as depicted in Figure 16. On the sixtieth day of observation, a significant increase in assimilation level was seen, reaching a value of 8, as depicted in Figure 17. This observation indicates the existence of a significant issue within the soil. On the 75th day, the data presented in Figure 18 demonstrates a slight decrease to 6.7, which remains within the severe range. On the ninetieth day of observation, a noticeable rise in the level of assimilation was recorded,

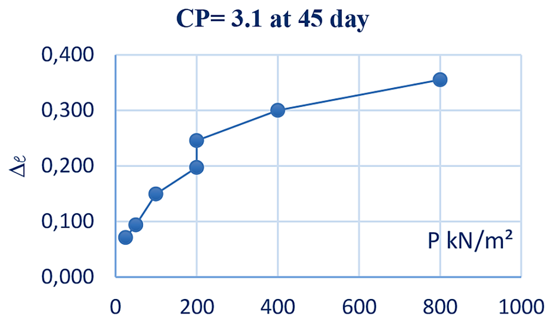



**Figure 16.** CP at 45th day curing

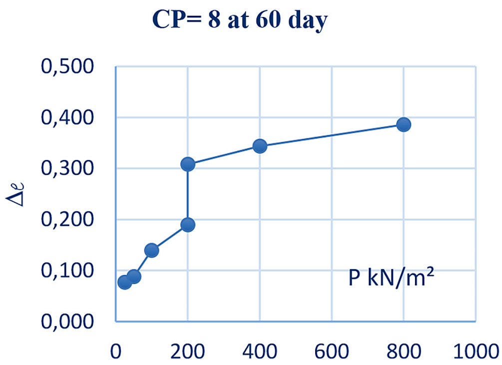



**Figure 17.** CP at 60th day curing

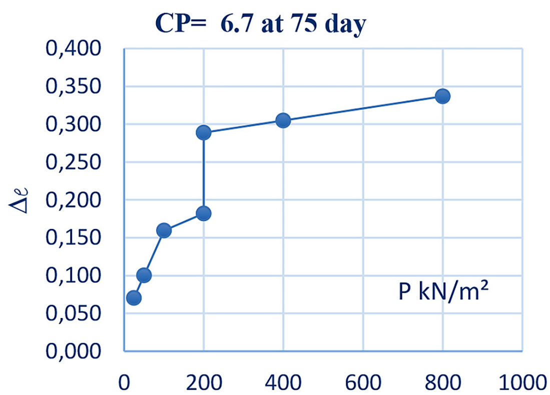



**Figure 18.** CP at 75th day curing

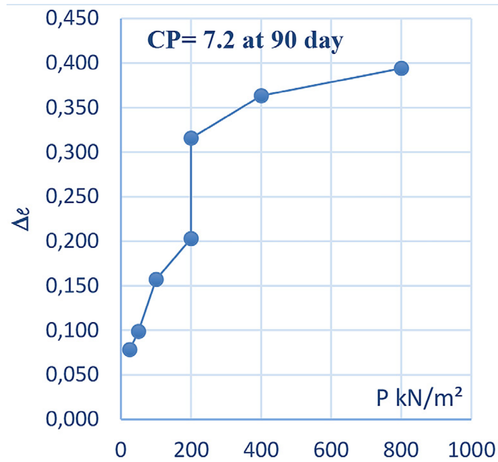



**Figure 19.** CP at 90th day curing

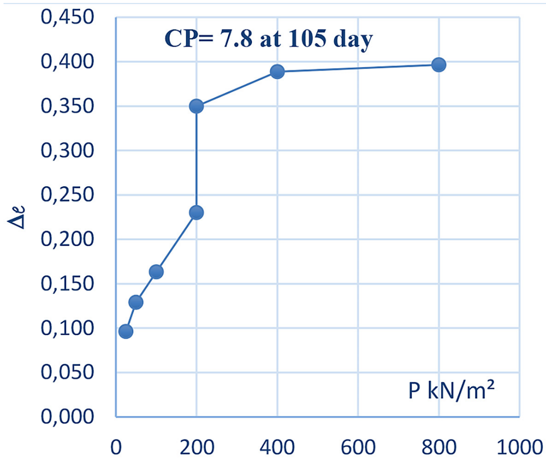



**Figure 20.** CP at 105th day curing

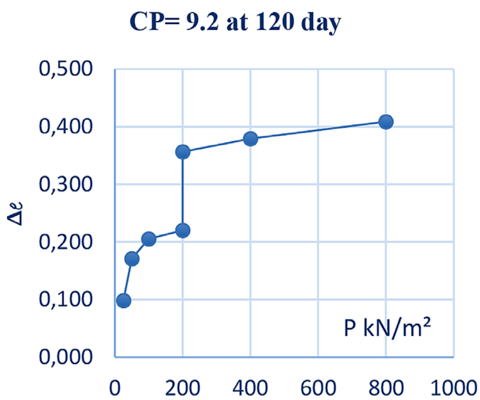



**Figure 21.** CP at 120th day curing

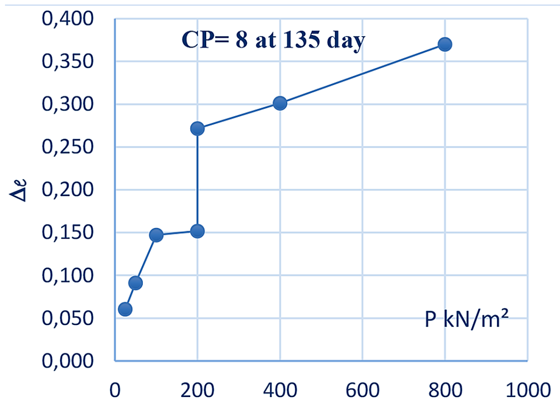



**Figure 22.** CP at 135th day curing

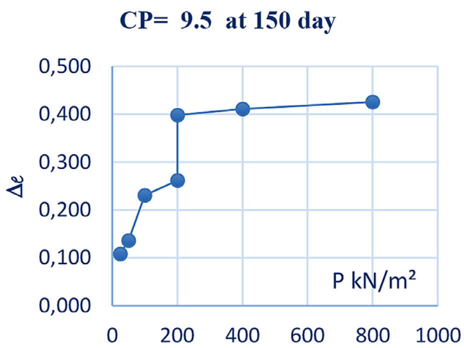



**Figure 23.** CP at 150th day curing

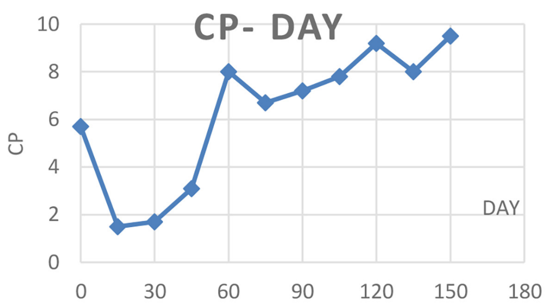



**Figure 24.** CP at 150th day curing

reaching a numerical value of 7.2, as depicted in Figure 19. On the 105th day, the measured value of 7.8, as depicted in Figure 20 displayed a consistent rising trajectory, remaining within the range indicating severe levels. On the 120th day, a significant increase in the level of assimilation was observed, reaching a value of 9.2, as depicted in Figure 21. This finding indicates a decline in the current state of affairs. On the 135th day, the value decreased to 8, as depicted in Figure 22, albeit it continued to fall inside the severe range. On the 145th day, there was an observed increment to 9.5, indicating a persistent decrease in the magnitude of the issue. Figure 24 displays the value of the fallout over time from day one to day 150, where the addition every 15 days is cumulative.

The supplementary material comprised a composite of ampicillin and avlagin, both of which fall within the category of pharmaceutical byproducts. The findings suggest a notable decrease in absorption levels over a period of time in clay soil. The problem initially displayed moderate attributes but later progressed to a severe and ultimately very severe challenge, as seen by the offered spectrum of assimilation classifications.

From an academic standpoint, the findings of this study suggest that the continuous injection of pharmaceutical waste into clay soil led to a significant decrease in absorption levels during the whole duration of the observation period. The decrease in absorption levels that has been observed indicates the potential negative effects on soil quality. This highlights the need to develop the techniques that may effectively manage or mitigate the impacts of pharmaceutical waste on clay soil.

## CONCLUSIONS

Recently, pharmaceutical environmental benefits and impacts have garnered attention. The properties and environmental as well as health impacts of these compounds need additional study. The pharmacy is medically advanced. Due to their extensive usage to treat numerous disorders, these drugs may create enduring environmental damage. To combat the environmental pharmaceutical contamination, comprehensive regulation that satisfies the current standards is essential, focusing on ecologically sustainable compounds.

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