Study of the influence of a Bioabsorbent derived from Orange Peel on a filtering soil using seawater irrigation by capillarity

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***Abstract*—** *The effect of rain on our planet has been the most important meteorological phenomena to be reproduced by humans. It has been vital for the hydration of the soil, making it possible for agriculture to prosper and progress. However, the great secret of irrigation is in the ground, in the water tables and aquifers that store and manage water, storing every drop of rain and distributing the water through the underground river basins, indirectly irrigating everything, from the mountain to the sea, making the cultivation of crops possible. This means that the type of soil is as important as the water supply.*

Irrigation for agriculture has always simulated rainfall; therefore, it has copied irrigation from above and has focused on the soil drainage capacity. From this point of view, saline water is not beneficial for this activity, but it may be the only source of irrigation water for arid regions, especially in developing countries, where there's a scarcity of water and the population is rapidly growing. Storing irrigation water for both agriculture and the increasing population is necessary for the developing country's prosperity.

The use of seawater applied to irrigation is not a new technique, there's evidence that proves that in 1719 the Sestao's Carmelite monks, located in Vizcaya, made use of this practice.

When considering the possibility of irrigation without desalination, always through capillarity systems, it is essential to consider some critical factors, such as the substrate of the ground, the distance of the water table, the salt composition of the seawater, chemical reactions of the ground with the salts or the drainage of the ground. Modifying any of these parameters can cause salinization effects, loss of humidity or desertification of the substrate, amongst others.

This study shows the influence of a bio absorbent obtained from the orange peel on the behaviour of a substrate based on silicon sand.

***Keywords*— Desertification, Desalination, Reusable, Seawater Table, Bioabsorbent.**

I. INTRODUCTION

Desertification is the result of climatic changes and human activity, which reduces productivity and the value of natural resources in arid and semiarid conditions (Aubréville, A.; 1949). This is the international definition established by the convention of the United Nations against desertification, approved on 17th June of 1994, and from that day a date has been commemorated as the World Day to Combat Desertification and Drought.

The main causes for desertification are the weather, erosion, ecological factors such as the kind of soil and ecosystem, as well as human activity. Before desertification occurs, there is a erosion of the ground: when the wind removes the excess of soil and dust particles from the ground, the soil then loses the water table and the regeneration of the soil becomes very difficult (Stringer, L.C.; 2008). The low drainage of the soil, torrential rains or drought are other phenomena that cause desertification. Climatic change is a harmful phenomenon, but the most harmful is human activity: fires, logging, overexploitation of aquifers, intensive farming, with massive use of chemicals, and some forestry practices (mountain or forest crops), etc. (FAO 2000).

Worldwide it is considered that a volume above 1.000 m^3 per inhabitant and year is normally more than necessary for domestic use, industrial and agricultural. In consequence, it is estimated that a watershed suffers a loss of hydric stress when the water availability per inhabitant is below 1.000 m^3/year or when the quotient between water withdrawal and historical annual average runoff is greater than 0.4. There are some basins of this type in North Africa, the Mediterranean region, the Middle and Near East, South Asia, North China, the United States of America, Mexico, Northeast Brazil, and the west coast of South America. The population of those who live in these basins is about 1.400 and 2.100 million people (Vörösmarty et al., 2000; Alcamo et al., 2003; Oki et al., 2003; Arnell, 2004).

Irrigation represents 70% of all the water extracted in the world and almost 40% is for agricultural production (Fischer et al., 2006). In fact, all the irrigated land represents 18% of all agricultural land in the world and produces 1.000 million tons of cereals each year, half of the total world supply. In fact, irrigated crops produce between two and three times more crops than those produced by rain alone. (Alexandratos, N., 2005).

In general, it seems that global warming will benefit the agriculture of developed countries in warm climates. On the contrary, the countries with a tropical or subtropical climate will suffer the effects of climatic change, and the dependence on imports from other countries will increase, as the difference between north and south, of alimentary security, will be accentuated (Canadell et al.,2007)..

Water management tends to improve the quality and quantity of available water regulating the use of water from the surface and underground, developing other sources of water, rationalizing water's consumption, or, controlling the contaminants and recovering them from wastewater through a depuration process. The objective of good water quality must be pursued in each river basin, so that measures relating to surface water and groundwater belonging to the same ecological, hydrological and hydrogeological system are coordinated (Directive 2000/60 / EC). From this point of view, the reuse of treated water is an essential element of the natural water cycle and, in fact, is seen as a measure to solve the problems of water scarcity.

Agriculture is the main cause of the lack of water around the world, 70% of all the water extracted and in some cases 95% in developing countries (FAO, 2017), is used for this activity, thereby reducing water availability for people.

It is expected that between now and year 2050, the demand for food will increase by 60% and the world's population will be around the 9.000 million (FAO, 2013). The actual and future situation will mean agriculture will need more and more water, and consequently lead to an increase in the global lack of water including those areas that currently have enough sources of water.

In order to reduce the agricultural pressure on the hydric sources, one of the possible solutions is the use of brackish or desalinated seawater. The advantage of the use of this type of water is that there are inexhaustible resources and they are not subject to climatic variations. So this type of water is strategically perfect to develop the availability of increased water resources for agricultural irrigation in water deficient areas. However, only the most advanced crops with higher economic margins can bear the costs of desalinated water (Martínez 2014). This desalinated or osmotized water is characterized by its low mineralization and significant imbalances in its composition. So it is not suitable for every type of supply (domestic, agricultural or industrial). In order to adapt the characteristics of the osmotized seawater to the requirements of the different uses, it must undergo post-remineralization treatments.

The depurated water reusability for crop irrigation is another option, and lately it has been used in many countries. Nevertheless, it is necessary to guarantee a minimum quality of water, as well as its functional uses depending on how it is treated.

On the other hand, another technique to address the lack of water and that hasn't been contemplated until now, is the use of seawater for the irrigation and development of crops.

The uses of capillary irrigation systems can offer a solution not only to the problem of water scarcity, but can also contribute substantially to the transformation of arid or desert areas into green areas and fields. It must be taken into account that the water rises in the soil due to evaporation and absorption by the roots of the plants. Water moves by capillarity (especially intense effect in arid climates) and by difference in humidity, (deeper ground levels remain wetter as they are protected, due to their distance from the soil surface, and from water losses due to evaporation and the absorption by plants). On the other hand, the water not only moves vertically, it also moves laterally. Therefore, it can be said that the water in the ground moves in any direction (Duchaufour 1978).

The use of seawater applied to irrigation is not a new technique, there's evidence that proves that in 1719 the Sestao's Carmelite monks, located in Vizcaya, made use of this practice. Later, on Oriñon beach (Cantabria) in 1959 a study was made of the use of seawater, without desalination, for irrigation, and achieving it without saturating the soil with salts (Esteban-Gómez, 1968).

Recently, there have been some successful investigations into the cultivation of chard using only seawater. One of the main characteristics is the low difference in height between the sea water and the crop (García et al., 2019), which is a good example of how to make a well-functioning irrigation system as well as reducing the costs. However, to successfully develop the cropping with higher yields, it is fundamental to optimize the substrate for the water and mineral supply of the crops. The tolerance conductivity of the soil will be a major parameter to control; otherwise, the salinity may affect the crops.

The objective of this study it to determine the influence of a bioabsorbent obtained from orange peel, on the behaviour of a substrate composed of silicon sand in order to reduce the salinity of seawater without a previous desalination, by applying this technique to capillarity irrigation.

II. MATERIAL AND METHOD

All the experiments for this project were carried out using capillary irrigation, which means that the seawater reached the substrates underground, and then rose through a tube.

Preliminary studies (García et al., 2019a) demonstrated that for irrigation it seawater can be successfully used, as long as it is supplied through the water table. However, this might not be enough, the soil is really important to optimizing irrigation with salty water. The kind of soil or substrate has to have particular characteristics (composition and granulometry) to reduce the salinity and store the humidity, in that way the crop can supply itself with water and nutrients as necessary, and at the same time, the salinity won't exceed the value limit to make crops grow. In all the previous experiments, the conductivity did not rise more than 2 mS/cm above 15cm ground level (García et al., 2019a). The fact that the soil can reduce the concentration of salts is possible because of the ion exchange between the water and the substrate. It is a dynamic process that develops on the surface of the particles, as a result of the electrical imbalances of the ground particles. In order to neutralize these charges, it adsorbs the ions from the solution of sand and sea water (Porta et al., 1994).

On this Project, silicon sand was used as a soil filter, as it is a material with great resistance to chemical compounds and water insolubility, and this is the reason why it is used as a swimming pool filter. The chosen granulometry was between 500-1000 µm, which has a very efficient drainage capacity and at the same time, enough capillary strength to absorb the seawater from the underground to the surface, because along the tube the silicon sand reduced the amount of conductivity.

A waterproofed channel with 80 cm long, 34.7 cm wide and 22 cm high was built with a drainage system to control the maximum height of the seawater. To facilitate water renewal a pump was used with a flow of 2L/day, working on an open water circuit. The aim was to create an artificial water table continually renewing the water and avoiding the formation of brines and an accumulation of salts from the salty water.

The technique used to check the ascension of the water was made using tubes of PVC, the diameter was about 57 mm, and so the section in contact with the seawater was of 25'51cm^2. The tubes were filled with the filtration samples and there were two types: the first one had silicon sand and the second type contained silicon sand with bioabsorbent at 5% w/w and a granulometry between 500-1000 µm. The samples with bioabsorbent could be divided in function by the physiochemical properties: there were samples with a bioabsorbent physically treated and another type that had a physical and chemical treatment. On Figure 1 it is shown a scheme of the samples and their contents. The total numbers of tubes used in the experiment were eighteen.

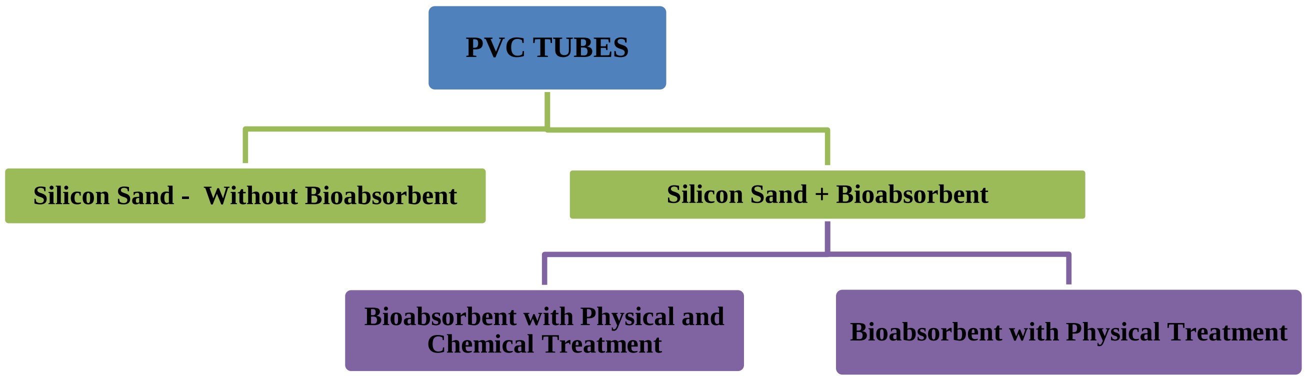

FIGURE 1: SCHEME OF THE TUBES AND TYPE OF SAMPLES

The first samples were extracted after sixteen weeks, and, at different heights, the values of pH, conductivity and humidity were measured using 9 tubes in total.

The remaining 9 tubes were subjected into a precipitation simulation. To do so, 500 mL of deionized water was added to the surface, and the samples were extracted at week eighteen, twenty and twenty-four, 2, 4 and 8 weeks after the water was added, respectively. The aim of this simulation was to check the behaviour of the ascension of the seawater through the variety of substrates with and without the bioabsorbent.

III. RESULTS

3.1 Results at week sixteen

Firstly, it can be appreciated that the seawater did not reach the surface of the samples that contained bioabsorbent, in addition, there appeared microorganisms (Figure 2). In contrast to the sample with silicon sand, in which the water reached the surface.

Sample Appearance at week sixteen

a) Reference substrate (Silicon sand) | **b) Substrate with bioabsorbent 5% physically treated** | **c) Substrate with bioabsorbent 5% physically and chemically treated**

FIGURE 2: Appearance of the samples at week sixteen

The rise of the water corroborated the interaction of the seawater and the bioabsorbent. The parameters measured were the pH, humidity and conductivity. The substrate was inside a PVC tube divided into four sections (Figure 3): the first one between the base of the tube and 11 cm, the second section between 11 – 14 cm, the third between 14 – 17 cm, and the last one on the surface of the tube 17 -20 cm.

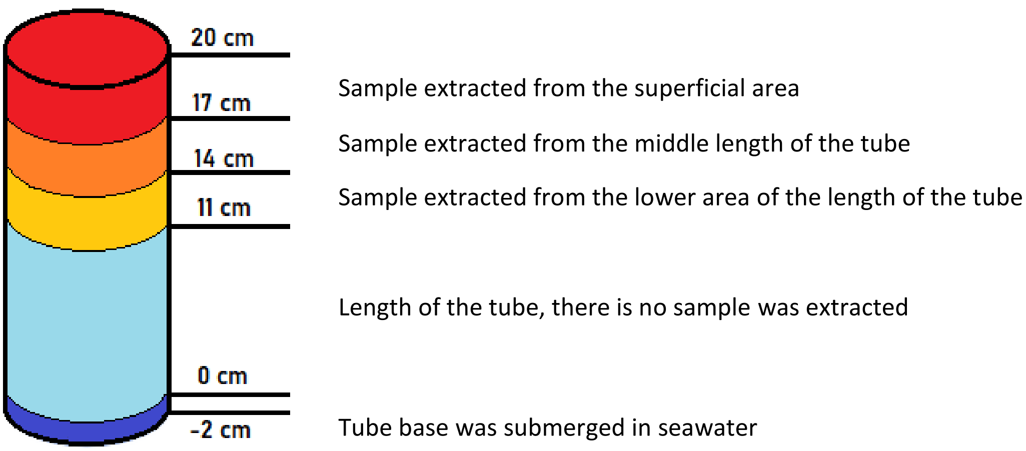

FIGURE 3: Scheme of the samples extracted showing the function of the levels of the tube

The percentage of humidity was determined gravimetrically. The methodology used to do so, was taking a sample with a known weight and gently heating on a stove in the laboratory for 24 hours at 110ºC. After this time, the sample was taken through a process of desiccation and then weighed again, with the difference weight showing the amount of water that contained the sample, and so the percentage of humidity. The stove used it during the process was a model Nahita 631/4 and a precision balance, model SCALTEC SBA 52

Once that the sample was dried, the level of salts in the sample could be determined. A known weight of the sample was taken and deionized water was added with a ratio of 1:5 (m/v), then it was agitated for 10 minutes. The next step was to let the silicon sand in the moisture sediment filter the liquid in order to separate the solids in suspension. Both conductivity and pH were measured at environmental temperature using a conductimeter Jeulin JLC20 and a Ph meter Thermo Scientific Orion 2 Star. The values of conductivity could now be used to determine the concentration of salts in the samples with a calibration line.

The pH values of the function of the kind of substrate are shown on Figure 4. There is a significant difference between the pH of the samples without a bioabsorbent, which is nearly neutral and the other samples with bioabsorbent at 5%, whether are chemically or physically treated.

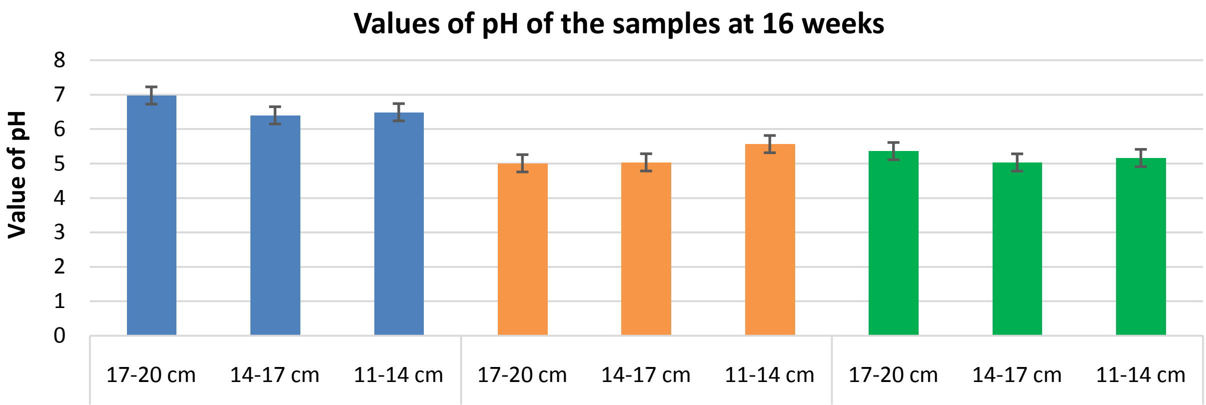

FIGURE 4: Values of pH of the samples at 16 weeks

The pH of seawater is between 7'4 and 8'5, and thus there is a definite interaction between the substrate and the seawater, increasing with the presence of the bioabsorbent. Probably, this interaction might be as a consequence of the microorganisms developed during the sixteen weeks.

Figure 5 shows the results of % humidity and conductivity on the samples extracted at week sixteen. In all the cases, the values of humidity were lower at the surface (17-20 cm), which means that the lower the height of the extracted sample, the higher the humidity.

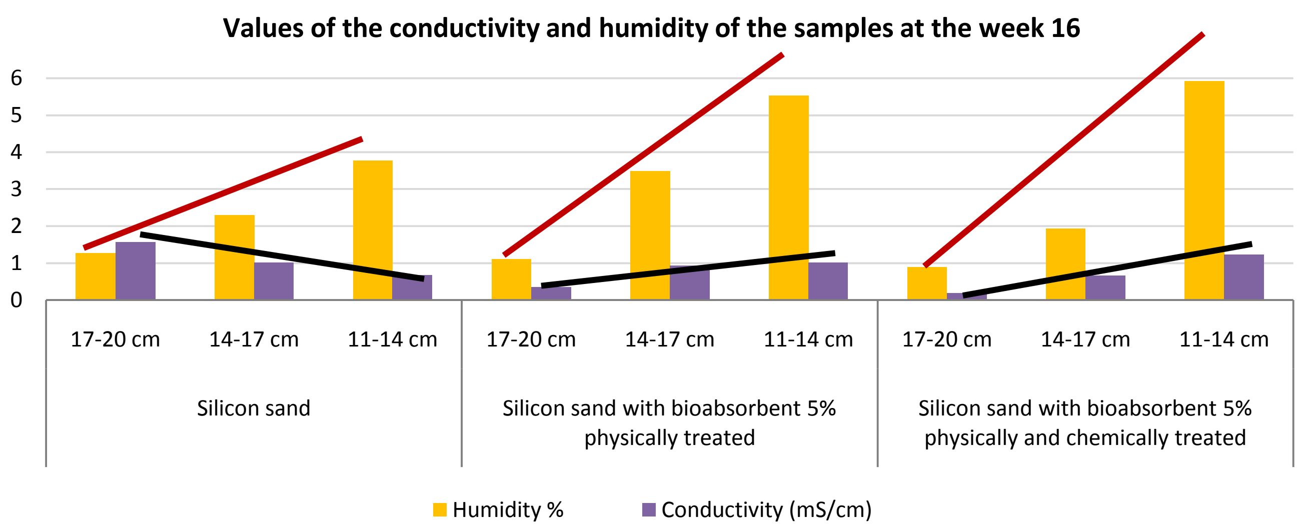

FIGURE 5: Values of the conductivity and humidity of the samples at the week 16

On the other hand, the values of conductivity were to the contrary depending on whether the sample contained bioabsorbent or not in the substrate with just silicon sand, the conductivity increased as did the height of the extracted sample, the highest value was at a level between 17-20 cm. This behaviour was the result of a self-munching effect: the seawater rose to the surface, where it was evaporated and the salts were retained and accumulated, giving an increase in the conductivity value.

The samples with silicon sand mixed with the bioabsorbent at 5% with a physical and/or chemical treatment had the opposite effect to what was seen in the preceding case. The bioabsorbent had an effect in reducing the conductivity as a result of the capacity of absorption which retained salts through the tube (García et al., 2020). It must be noted that seawater has a conductivity of approximately 50 mS/cm. Once it had risen through the tube and reached the surface, the conductivity was below 2 mS / cm, so the reduction in salinity was really important.

3.2 Results at week eighteen, twenty and twenty-four

Furthermore, when the samples were pulled out at week sixteen, 500 mL of deionized water were added to the other samples, imitating rainfall. The soil contained seawater or the salts of it, so the water entered thorough the pores from the surface level and filtered into an already saturated regimen. When the soil is completely saturated with water from rain or after irrigation, the pores are filled with water and in this condition, as a result of the force of gravity the water descends into lower levels. It was this process that we artificially imitated and observed the effect on the conductivity values.

The aim of the leaching process was to test the capacity of regeneration of the soil, in this case the silicon sand, by measuring the conductivity of the samples. Hence, the conductivity was the most important parameter to be analysed, because it showed if the soil was or was not able to regenerate in situ, because in the case of a big increase in cropping, the irrigation by capillarity would make the soil impossible to be constantly replaced. In Figure 6 the conductivity values of the samples of silicon sand over twenty-four weeks are compared.

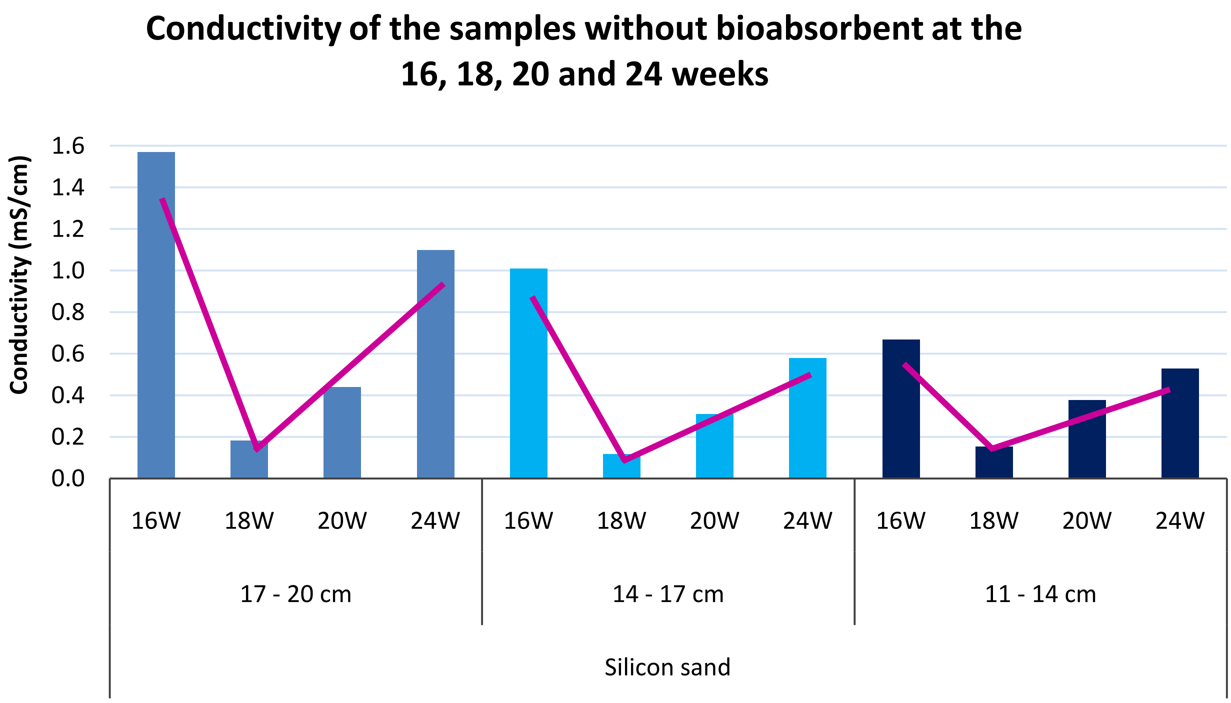

FIGURE 6: Conductivity of the samples without bioabsorbent at 16, 18, 20 and 24 weeks

The conductivity of the sample at week sixteen was the highest in comparison to the samples that were extracted on week eighteen, twenty and twenty-four. The addition of deionized water at that point develops a leaching process, and the minimum value of conductivity was obtained at week eighteen. This parameter increased over the next few weeks. However, the conductivity value at week 24 did not reach that of week 16. Therefore, in those eight weeks after the addition of deionized water on the substrate surface, the conductivity value never reached the experienced value during the first 16 weeks.

The behaviour of the sample without bioabsorbent was the same as the samples that contained bioabsorbent at 5% w/w with a chemical and/or physical treatment (Figure 7).

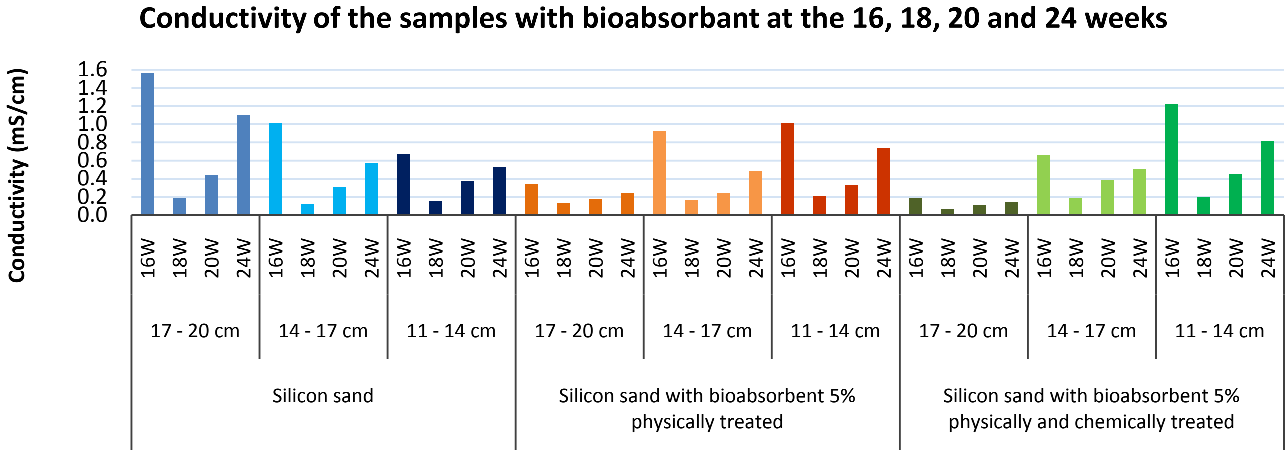

FIGURE 7: Conductivity of the samples with bioabsorbent at the 16, 18, 20 and 24 weeks

Figure 8 shows the pH of the samples studied at the time of the extraction. At week twenty-four the sample without bioabsorbent had stabilized at 7'5. Conversely, the presence of a bioabsorbent that had been chemically and/or physically treated had a significant influence on the values obtained at the base of the PVC tube (11-14 cm). In the middle and higher levels (14-20cm) of the tube, the values were more acidic, which confirmed the interaction of the substrate and seawater as seen before week sixteen, and probably as a consequence of the development of the microorganisms.

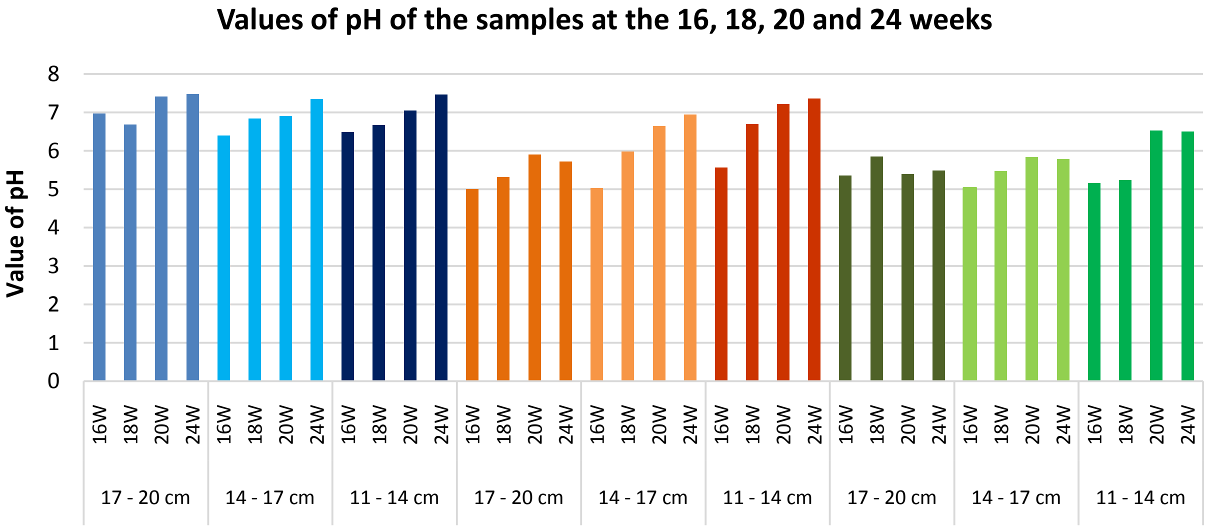

FIGURE 8: Values of pH of the samples at the 16, 18, 20 and 24 weeks

IV. DISCUSSION

Bioabsorption is a physiochemical process like adsorption or ion exchange, which consists of adsorbing chemical into the cellular structure of a biomass like algae, fungi, bacteria, fruit shells, agricultural products or some biopolymers (Chojnacka 2010).

The cellular walls of the bioabsorbents contain polysaccharides, proteins and lipids which have the capacity to bind heavy metals and cationic molecules to the surface. These compounds have functional groups like amines, carboxylic, hydroxyl, phosphates and thiol, each one has a different affinity and capacity to bind different metallic ions (Ghimire 2003).

The orange peel (Citrus sinensis) is obtained as a by-product of orange juice production and normally treated as a waste. Even so, from the pectin (citric pectin) can be extracted essential oils, which has a multiple uses in the pharmaceutical and feeding industries. However, orange peels similar to other citric fruits have been used successfully to eliminate heavy metals and textile dyes. (Hameed 2008; Li 2008; Gupta 2009; Lu 2009).

Depending on the source, pectins can vary in molecular size, degrees of acetylation and methylation, galacturonic acid content, and neutral sugar residues. This means that pectin might have versatile gelling properties and form complex compounds with other natural compounds, and therefore, due to their properties, pectins are useful in creating new alimentary products (Gawkowska et al., 2018).

The product obtained after the pectin extraction is a poor food supplement for animals, which has a low protein but high sugar content (Siles et al, 2016). Regardless of that, it has the optimal properties for an after treatment as a bioabsorbent (Masmoudi et al, 2008).

The extraction of the soluble pectin in an acidic medium is necessary to develop its capacity to absorb great quantities of water and form colloids. If it wasn't extracted, the product would not have an appropriate level consistency to be used as a bioabsorbent. The acid hydrolysis makes possible the solubilisation and degradation of carbohydrates, especially xylan and hemicellulose, since glucomannan is a relatively stable compound in an acidic medium. (Van Buren, 1991).

An initial acidic treatment is required to be completed in order to increase the absorption capacity of the citric peel, and then the next phase is an alkaline treatment. The aim of the process in an alkaline medium is to saponify the functional groups of esters, which have not been extracted during the original acidic process (Cardona Gutiérrez et al, 2013). In general, the NaOH is used for the alkali process, added after the $CaCl_2$ with the objective of increasing the activation. However, it has been already demonstrated that both process might be done in a combined phase using the $Ca(OH)_2$ 0.2 M (Arjona et al., 2018).

The use of a bioabsorbent 5% w/w with the silicon sand improved the behaviour of the substrate decreasing the salinity of seawater. The results of the tests of the bioabsorbent with physical treatment (orange peel subjected to a drying process to give a constant weight plus subsequent grinding with a granulometry between 500-1000 µm), were improved using a bioabsorbent with a chemical treatment and a granulometry between 500-1000 µm too.

In all the cases, the experimental values of conductivity were under 2 mS/cm (Table 1), this is the limit value for successful cropping without negative consequences for the plants, and it is important to note that a lot of water for drainage, including subterranean sources is between 2-10 mS/cm (Rhoades et al., 1992). Obviously, to successfully develop this new technique of irrigation, the substrate will have to be optimized in order to use it on an industrial scale and also have the water and nutrients available which are necessary for successful cropping. The tolerance salinity of the soil will have to be revised so as to not exceed the limits of the values for successful cropping.

TABLE 1
TYPE OF SOIL IN FUNCTION OF CONDUCTIVITY

Soil type	Salinity	*Conductivity (mS/cm)*	Effects	*Crops*
Normal	Very light	0-2	No effects	Corn, lemon, apple, peach ...
	Light	2-4	Might affect sensible crops	Rice, olive trees, tomato plants, melon, spinach ...
Saline	Medium	4-8	Effects majority of crops	Wheat, soy, cotton, barley, beet ...
	Strong	8-16	Cropping is difficult	-------------------------

V. CONCLUSIONS

- The use of seawater for capillary irrigation is possible as is demonstrated by this project.
- The soil must have specific characteristics in composition and granulometry in order to reduce the salinity. At the same time, the soil must keep the humidity at a certain level for the roots of the crops, because of the need for hydration and nutrient absorbance.
- If the seawater does not show a decrease in salinity it would be completely detrimental to crop growth. Silicon sand meets these requirements and can be regenerated by leaching with fresh water. In addition, this kind of soil or filter medium, silicon sand, can be found all over the world and is an economic and abundant medium.
- From a height of 10 cm from the seawater level, the experimental values of electrical conductivity were less than 2 mS/cm.
- The mix of the silicon sand and bioabsorbent obtained from orange peel contributes efficiently in the retention of salts from the seawater. This type of filter medium contains two components that are easy to find: silicon sand, which can be found all over the world, and orange peel is a poorly used waste from the food industry.

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