Decontamination of heavy metals in water with orange peel in México

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Abstract
One of the most alarming and worrisome problems in Mexico is the contamination of water with heavy metals. Several studies carried out, that water pollution has been increasing in different parts around the country. Our project seeks to create a viable, environmentally friendly and sustainable alternative to eliminate water polluting agents such as mercury, cadmium and lead, as well as generating an option for the use of organic waste derived from the growing demand for fruits that exists nowadays. Our project, also seeks to innovate a model for the decontamination of heavy metals from water, with the aim of providing a chance to the people most affected by this problem, which in this case are those with lower socioeconomic status, that do not have access to the purchase of filters or special equipment for the decontamination of heavy metals from water.

Keywords
Orange peel, decontamination in water, decontamination of mercury-Cadmium-Lead

1. Introduction
Heavy metals cause environmental concern, because they are not degradable, they are persistent and toxic when they are present in nature (Gupta and Ali, 2004). Toxicity at high levels leads to adverse effects on health, generally associated with high concentrations of lead, cadmium, mercury and arsenic. Industries such as mining, metal processing, electroplating and electronics release high amounts of mercury, cadmium, arsenic to the environment which generally pose high health risks (Liu et al, 1997). The neurological complications caused by the ingestion of mercury in infants is mental retardation, seizures, loss of vision and hearing, in addition to developmental delay, language disorders and memory loss. In adults, the neurological symptoms are: tremors, insomnia, memory loss, neuromuscular effects, headache and cognitive and motor dysfunction (WHO, 2017). Despite damage to human health, the pollution of mercury also seriously affects the environment.

Conventional methods for the removal of heavy metals from wastewater include reduction, precipitation, ion exchange, filtration, electrochemical treatment, membrane technology and evaporative disposal, all of which may be inefficient or costly unacceptable, especially in the case of metals dissolved in large volumes of solution at relatively low concentrations (Ozcan et al, 2005). Adsorption is considered an effective, efficient and economical method for water purification (Gosset et al, 1986). Our project aims to implement a new method of filtering heavy metals in water with orange peel, which will be sought viable, effective, efficient and economical for the benefit of the most vulnerable communities to this problem.

The orange (Citrus sinensis) cultivated in the subtropical climate, is classified in the Rutaceae family. The citrus flavor is one of the most popular fruit flavors for drinks. The taste of orange juice has been studied more than any other type of citrus fruit (Selli et al, 2004). On the other hand, the orange peel is a non-toxic low-cost bioadsorbent, thanks to the fact that it contains hydroxyl and carboxyl functional active groups, present in the cellulose, hemi-cellulose and pectin components (Feng et al, 2009., Liang et al, 2009). The byproducts of citrus processing represent

a rich source of flavonoids of natural origin (Horowitz, 1961). The peel that represents approximately half of the fruit mass contains the highest concentrations of flavonoids in citrus fruits (Manthley & Grohmann, 1996, 2001).
According to the Statistical Database of the Food and Agriculture Organization of the United Nations (FAOSTAT), the world production of oranges in 2007 was estimated at 63,906,094 tons. A high percentage of this production (70%) is used to make products such as juice or jam. In addition, approximately 50 to 60% of the fruit is transformed into waste, which consists of the husk, seeds and membrane residues (Wilkins et al., 2007).
In previous studies, the effectiveness of the orange peel as a bioadsorbent is shown. Feng, Guo and Lian (2009), verify the bio adsorption effectiveness of the chemically modified orange peel with sodium hydroxide and calcium chloride with a maximum capacity of Biosorption for Cu (II) of 72.73 mg / g. For its part, Hashemian, Salari and Yazdi (2014), studied the preparation of activated carbon from agricultural wastes for the adsorption of 2-pic in aqueous solution, affirming its effectiveness.
Other research analyzes the use of orange peels as a potential adsorbent for arsenic (III) in aqueous solutions (Shehzad et al, 2018).
Previously studies enrich our reach to propose a way of decontamination the heavy metals from the water in Mexico.

2. Methodology for the design of the product and the process

The proposal of our project seeks to be a viable and sustainable option, since the current trend is the reduction of pollutants and processes that may affect the environment. In our project, we seek to provide a sustainable method, addressing the problem of organic waste derived from the growing demand for fruits that predominates today.
This problem is tied with the need to purify the water of heavy metals, which comes from the idea of using an organic element. In this case, the orange peels take advantage of its properties, and performs the decontamination of heavy metals from water. The properties presented by citrus fruits makes the process viable due to the attractiveness of the minerals inside the peels.
Using the attraction capacity presented by the orange peel, a filter can be developed, which will allow the adsorption of heavy metals from the aqueous solution, making purification feasible and drinkable to human race.
To start the process, the orange peels need to be subjected to a process of cleaning, dehydration and sieving so that later they can be used as a filtering agent where they will be mixed with a previously contaminated solution.
The dehydration of the orange peel will be carried out to be sieved to 150 microns, to demonstrate our initial hypothesis trough tout different tests **(**Hernández, 2019**).**

2.1 Process of dehydration

For this process, a total amount of 5 kilograms of orange peels were used, which were washed with the objective of removing possible contaminants or impurities that could have adhered to the peel. In figure 1, the orange peel can be observed prior to dehydration.

Figure 1. Orange peel prior to dehydration

The process of dehydration begins when weighing the raw material, as you can see in Figure 2. Subsequently, the material was concentrated in two trays and covered with aluminum foil.

Figure 2. Weight of raw material

For this process, an EDEL industrial dehydrator was used as in Figure 3, which it was programmed to heat the orange peels to 45 or 60 degrees, the dehydrator was operating a total of 30 hours, changing the temperature periodically to ensure that the dehydrator did not damaged the material. Orange peel was dehydrated first for 4 hours with a decrease in weight from 5 kilograms to 1.075 kilograms. Subsequently, the orange peel was dehydrated for 26 more hours, and suffered a decrease in weight from 1.075 kilograms to 0.643 kilograms of material.

Figure 3. Industrial Dehydrator

The process of dehydration should continue the weight loss, until the material is zero kilograms; This means that you have completely lost your weight in water.

2.2 Sieving process

For the following process, there was a total of 0.643 kilograms of dehydrated orange peel. With the dehydrated orange peel, a blender was used to grind the material. Then, the milled material was passed through a 150-micron mesh to further decrease the grain size (Espinosa, 2019), the total sieving time was approximately two hours, as you can see in Figure 4.

Figure 4. Material sieved at 150 microns

At the end of the process, a total of 130 grams of final product refined to 150 microns were obtained for its later use as a contaminated water filter.
During the development of the investigation, it was necessary to make a flow diagram of the process to have a clearer way of which activities would be generating value to the client and in this way to focus on the efforts for the continuous improvement of the activities. The diagram can be seen in figure 5. In the diagram, the activities with a green background represent those that are believed that they add value to the final product and, therefore, also to the customer who makes use of the contaminated water filter.

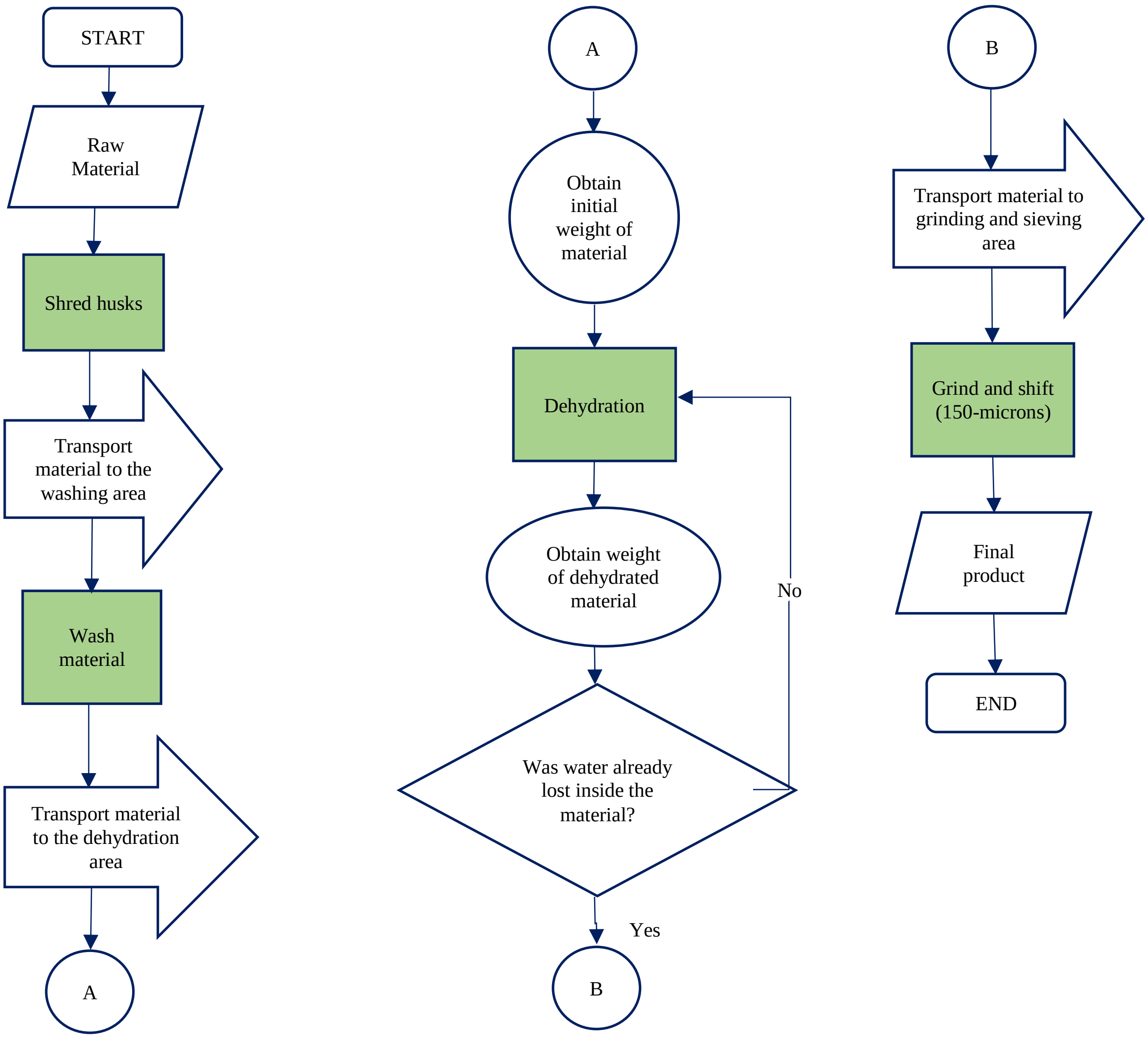

Figure 5. Process flow diagram

3. Development of experimentation

During the development of the hypothesis testing process, samples of water contaminated with different concentrations of metals will be collected to discover the efficiency of the orange peel.
Water contaminated with mercury (Hg), cadmium (Cd) and lead (Pb) were provided by the Water Center of the Technological Institute of Monterrey (ITESM). The water samples were presented with different levels of contamination: they were in a range of 10 parts per billion to 100 parts per billion. The OMS have certain guidelines for the amount of metals that water can contain and that it remains potable. For Cadmium, the OMS indicate 3 µg / L; for Lead, 10 µg / L are indicated and for Mercury, they are 6 µg / L.

The samples with contaminated water were grouped as follow: 250 ml of contaminated water separated into 20 samples: 10 of Mercury with concentrations of 10 to 100 parts per billion and 10 of a mixture of Cadmium and Lead with concentrations of 10 to 100 parts per billion.
The sample with 250 ml of contaminated water were introduced exactly with 4 grams in the final product of the previous process: the orange peel sieved at 150 microns. To ensure that they were 4 grams of finished product, a spoon was used to pour the material into the beaker. Both the beaker and the ladle were washed with distilled water to ensure decontamination of the material. The weight of the beaker was 50 grams, material had to be introduced until its weight reached 54 grams of beaker with the addition of the sieved material.
The result can be seen in Figure 6, 20 plastic bottles, each with its respective sample of water contaminated with Mercury, Cadmium and Lead in addition to the respective 4 grams needed to make the filtration.

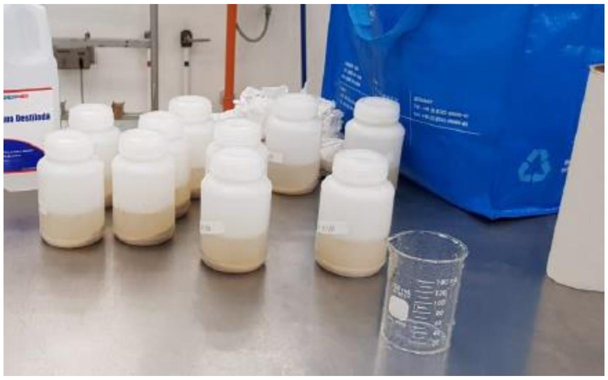

Figure 6. Samples

The next step of experimentation involves shaking each container for 30 minutes.
The bottles should be shaken because that guarantees that it has a great amount of contact between the contaminated metal water and the orange peel filter. After being stirred, they should be left to rest for a day and then stirred for 15 minutes each to continue the contact between the filter and the water. Figure 6 shows the samples analyzed.

3.1 Filtration

The filtering process was carried out at the University of Monterrey (UDEM). This process begins with a support and clips to hold a funnel over a beaker that will collect the decontaminated metal solution. The funnel and the beaker must be previously washed with distilled water to decontaminate them. Next, a Whatman 40 filter is placed in the funnel to filter the water. Then, the solutions are emptied with the sieved powder and the metal solution in the funnel and wait until all the solution are filtered. When the solution finishes filtering, it is emptied into another vial already labeled. This step must be repeated for the 20 samples of contaminated water of Mercury, Cadmium and Lead that are then sent to be analyzed to find the remaining concentrations after filtering.
After the filtration process, these results show a sample that satisfactorily managed to purify the contaminated water with 202Hg (ppb). This shows that the sample with orange 10 is the one that should be used in future projects.

Conclusion

During the development of the present project, multiple laboratory tests were carried out. The results obtained in the project were satisfactory since the orange peel gave us positive results in the decontamination of mercury, with these results we will have a basis for future research and creation of innovative products at low cost and with a considerable environmental impact, since nowadays in Mexico, pollution and lack of water is one of the most critical problems, especially for people with lower socioeconomic status.

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Biographies

Jacobo Tijerina-Aguilera obtained his Bachelor's and Master's in Industrial and Systems Engineering and his Master's in Industrial Engineering at Tecnologico de Monterrey, Mexico. He is currently working towards his Ph.D. degree in Design, Manufacture and Management of Industrial Projects at Universitat Politècnica de Valencia, Spain. He is the Dean of Extension, Consulting and Research at Universidad de Monterrey, Mexico, and has been a trusted advisor to many Fortune 500 companies. His research interests are Operational Excellence, Innovation and Management Consulting

Nancy Lucero Tapia Ruíz is currently studying a Master in Product Engineering in Universidad de Monterrey, México. As a scholarship holder, she works part time as a research assistant with the Dean of the Division of Extension, Consulting and Research from Universidad de Monterrey. Lucero has worked in the manufacturing area with companies like LG Electronics and John Deere. She also used to work for Universidad Autónoma de Nuevo León in the division of manufacturing. Her research interests are lean manufacturing and operational excellence.

María Guadalupe Moreno Treviño obtained his Bachelor's in Midwifery Surgeon, his Master's in Science and Doctoral in Science with specialty in Morphology at Universidad Autónoma de Nuevo León. She works like a Basic

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