Proceedings of the International Conference on Industrial Engineering and Operations Management
Toronto, Canada, October 23-25, 2019

Decontamination of heavy metals in water using Operational Excellence as a quality tool

Jacobo Tijerina Aguilera y Nancy Lucero Tapia Ruíz
Extension, Consulting and Research Division
Universidad de Monterrey
San Pedro Garza García, Nuevo León, México
jacobo.tijerina@udem.edu, nancy.tapia@udem.edu

María Guadalupe Moreno Treviño
Basic Sciences
Universidad de Monterrey
San Pedro Garza García, Nuevo León, México
maría.moreno@udem.edu

Abstract
The contamination of heavy metals in water is one of the most critical problems Mexico is facing nowadays, with a latent risk, it is damaging the human health. Making use of technology and quality methodologies such as Operational Excellence (OE), we seek to find a balance to arrive at the consolidation of a scientific project accompanied by the OE methodology, to ensure the success of the project. In addition, it seeks to manage it with a wider vision, aiming at quality standards at a higher level, controlling operations to achieve a competitive advantage, having permanence in the market, providing a high quality and profitable product with innovative applications and trends. Therefore, our project provides a new method for the decontamination of water with a natural bioadsorbent based on grapefruit peels, and where it seeks to solve a problem without harming the environment at affordable costs to society.

Keywords
Operational Excellence, decontamination of mercury-Cadmio-Plomo

1. Introduction
Due to the industrial expansion in Mexico, water potability goes through very critical moments, in states like Nuevo León, the issue of drinking water and lack of water worries society, since every time the situation becomes a more critical subject. The objective of this project, is to propose a new method to decontaminate heavy metals such as lead, mercury and cadmium from water, making use of technology and also to guarantee the viability of the project by applying a quality methodology such as Operational Excellence that allows us to guarantee the success of this project and that will lead us to stay in the market. Heavy metals are pollutants with a very high level of hazard, for example, mercury ranks third among the most toxic elements for humans according to the Register of Toxic Substances and Toxic Diseases (ATSDR) (ATSDR, 2012). In addition to this, it also affects aquatic ecosystems, and this is due to their persistence, low biodegradability and high toxicity at low concentrations. On the other hand, in a study carried out by the National Water Commission CONAGUA in 2017, there were 5028 monitoring sites operated by CONAGUA throughout the country, the study showed that 29.21% of the sites were cataloged with red color presenting non-compliance in the toxicity of water. The underground water network consisted of 1240 monitoring sites. In this case, it was found that 33.87% of groundwater presented red color, due to non-compliance with the following parameters: fluorus, fecal coliforms, nitrate nitrogen, total arsenic, total cadmium, total chromium, total mercury and total lead. [twenty]. Currently, there is a wide range of solutions to extract or adsorb these metals from water, such as plant elements, phytoremediation, microorganisms, microstructures materials, packed biomass, but nevertheless these have a considerable disadvantage due to their high commercial value.
Our project aims to launch to the market a filtering material made from an organic waste, which besides being ecological, is low cost for society. One of the most important benefits of our project, is that our main raw material is based on a hundred percent natural product, which in this case is the grapefruit peel. But in addition, this is a product

that serves as a low-cost filter element, our project is profitable and encourages companies to invest in this type of technology, which, besides being low cost, has a considerable environmental impact.
To start the project, it is necessary to understand how the methodology of Operational Excellence works, this with the objective of applying its principles during the development of the project.

2. What is Operational Excellence?

Operational Excellence is a methodology widely used in the contemporary market, since organizations seek to improve performance in order to reduce costs, produce higher quality products in shorter execution periods (Garza-Reyes et al., 2012). It can also be reflected, as the consequence of the practice of ideal behaviors of the entire organization based on the correct principles (Shingo Institute). State where each employee can see the value flow of the client and detect failures in this before creating potential conflicts (IOE).
For Kumar, Operational Excellence is the section in which the organization achieves high quality standards through the development of innovation, technology in the development and distribution of products and services (Kumar, S 2015). The OE is doing things well to achieve a competitive advantage, with safe operations, reliability, product quality and efficiency (Honeywell Users Group 2009).
In addition, it provides us with enablers to generate competitive benefits in the resources of an organization. Change and optimization of business processes. Therefore, OE is the dynamic capacity to make processes efficient and effective in the value chain, using technological, cultural and organizational factors in an integrative manner (Gleich et al 2018). It is important to consider that the principles of Operational Excellence will only give results if they are integrated into the organizational culture (Miller et al.)

2.1 How to apply Operational Excellence in the project

To achieve excellence, it is necessary to practice effective communication and evaluation of the requirements. We must ensure that the requirements are clearly established in addition to periodically assessed the requirements to promote operational excellence (Bigelow 2002).
The OE allowed us to start with an adequate planning, with a strategic management and of course an effective communication in each part of the project since we agree that for a project to be successful it is important to have a good management. Our vision was to achieve a successful project execution, where all the participants contributed to the project, with a focus on the continuous improvement of our process in laboratories, offices and field.
According to Seán, one of the key points to achieve excellence in operations is to have a prior knowledge of this methodology. For this reason, the members of the project previously delved into the issue, created council meetings to develop well-defined plans and strategies and how they would be working to reach them, as well as discussions about Operational Excellence in the development of the project, raising improvement initiatives.
Operational Excellence has five core corporate competencies that can be easily aligned with the four dimensions of the Shingo model, each supported by behaviors of the leader and each team member, these are (Seán, K. 2007):

1. Build (develop yourself, your team and the organization)
2. Innovate
3. Anticipate
4. Establish vision and strategy
5. Deliver results

Another model on which we also base ourselves is the one proposed by Tijerina and Tapia (2018), this can be seen in Table 1. In this table, you can find the key points to understand the concept of operational excellence, a conception of these authors for operational excellence.

Table 1 shows the Operational Excellence program proposed (Tijerina and Tapia 2018)

Operational Excellence Program	
Theory	High business strategy, aimed at improving the efficiency and effectiveness of our processes, with a punctual approach to the culture of the people

Application guidelines	1. Optimize business process 2. Control the operations 3. Making a process lean 4. Strategic flexibility 5. Process improvement teams 6. Everyone knows the why behind the how and the what 7. Fast response to customer demand 8. Reliable products or service
Focus	Complete results as whole organization in every level, focus at process, focus at client
Assumptions	Using different tools from quality management, like: Lean manufacturing, six sigma, leadership; organization will operate with the highest levels, where, employees could see the client-flow and getting to know the process from "why" and "how"
Primary effect	Optimization and control process
Secondary effects	1. Effective and efficient processes 2. Organizational culture 3. Customer intimacy 4. Elimination of non-value-added activities 5. Lean processes 6. Strategic Planning
Criticisms	The model tends to be little accessible for small organizations, sometimes in a general way it is applied incorrectly

3.Improvements in the decontamination process

3.1 Procedure for the extraction of fat or oil from the sample

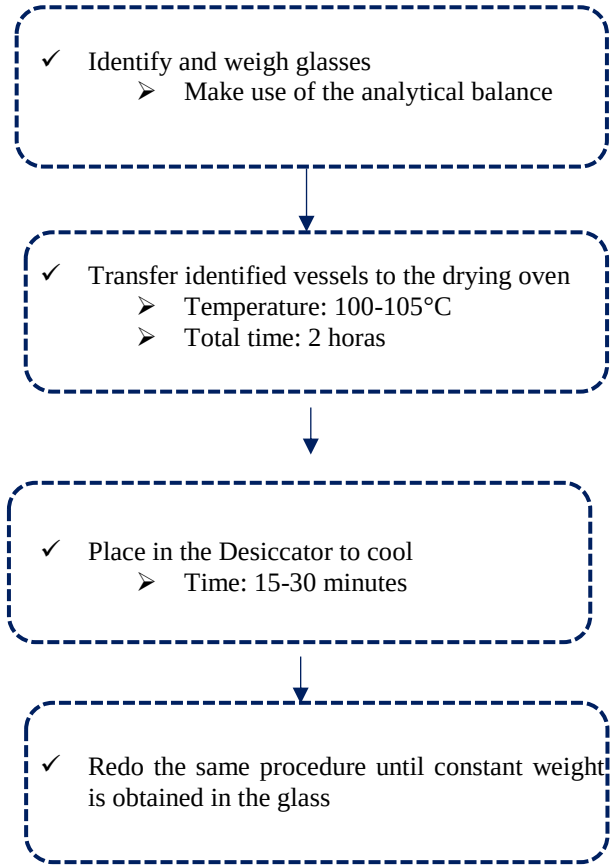
The fat content in the grapefruit peel was made using Goldfish's organic solvent extraction gravimetric method, following the NMX-F-545-1992 Standard **(**Loera-Hernández, 2019**).**
The materials that were used to perform the test are shown in Table 2. Table 3 shows the procedures performed for fat extraction from samples.

Table 2. Materials, equipment and reagents used

Material	• Glasses for fat (Goldfish) • Extraction cartridge (thimbles) or filter paper • Glass recovery tube • Cups forceps
Equipment	• Goldfish extraction apparatus • Desiccator • Analytical balance • Drying stove
Reagents	• Ethyl ether

Table 3. Procedures carried out for the extraction of fat from the sample

Previous procedures	**Procedure for the extraction of fat**



- Place sample inside the cellulose cartridge or thimble
- Place the thimble inside the dental holder and attach it to the Goldfish device
- Dry the goldfish beaker from the desiccator with the tongs and add approximately 60 milliliters of ethyl ether to each beaker.
- Place it in the Goldfish team. They are inserted into the condenser with a screw ring to prevent any escape of ether
- Verify that the water taps to cool the equipment is open
- The burner is raised until it contacts the glass. Ignite the burner in low temperature. And from the beginning of the reflux of the solvent, take the time to extract the sample for 4-6 hours at a rate of a drop of 2-3 drops / second
- At the end of 4-6 hours, turn off the equipment, remove the glasses from the grills
- Place the ether recovery tubes in the Goldfish device and replace the vessels to start the recovery of the ether
- Remove the glasses
- Empty the fat obtained in 15 ml conical tubes.
- This same procedure was done in triplicate to obtain a higher fat content.

3.2 Procedure for the digestion of the sample

In the present test, the objective is to digest the content of the citrus sample using the acid digestion method. In the Mars microwave equipment, CEM for its subsequent treatment in heavy metal analysis. In table 4, the material, equipment and reagents used can be observed for digestion processing in samples. In table 5, the procedure followed in the laboratory for the digestion of the grapefruit peel is presented.

Table 4. Materials, equipment and reagents used

Material	• Digestion vessels with their respective lids and jackets
Equipment	• Mars microwave, CEM • Analytical balance • Extraction hood
Reagents	• 70% HNO_3 • HPLC water

Table 5. Procedure for the digestion of grapefruit peels

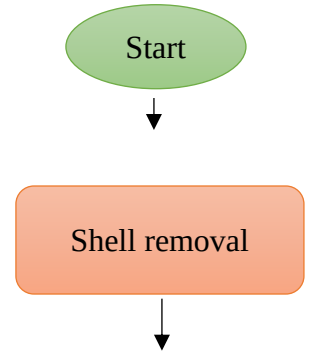
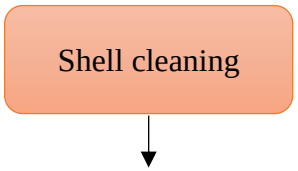
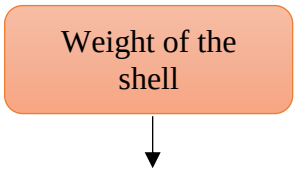
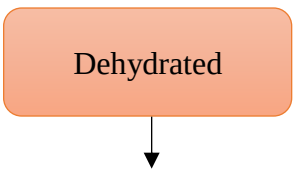
Procedure digestion of grapefruit peels

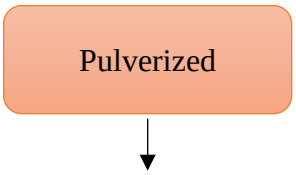
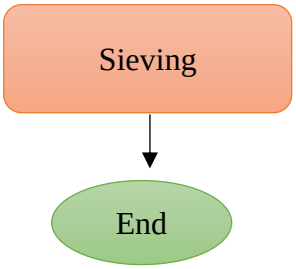
- Weigh grapefruit peel with the help of an analytical balance
- Place sample in microwave glasses
- Add 70% HNO3 and stand 15 minutes in the bell
- Cover the glasses, mount them on the carousel and place it in the microwave
- Continue the digestion of the samples by programming the microwave
- Finished digesting the samples, remove the carousel, remove the tubes and open them to adjust to 25 ml with water grade HPLC
- Transfer to 15 ml vials

3.3 Methodology for the design of the product

Table 6 shows the process that was carried out to obtain the filtering material.

Table 6. Process for obtaining filtering material.

Process	Description
	Obtain 5 kilos of Grapefruit peel
	It is necessary to clean the shell in small pieces
	Once the peel is cut it is necessary to weight it
	Introduce the industrial dryer to eliminate water, with changes in temperature to generate heat flows and improve dehydration times
	Dehydrate for 40 hours, it is important to consider that the shell must be free of moisture
	Grind the dehydrated shell to a powder, in addition to determining the percentage of moisture.

	
	Spray in mill with time of 1 to 2 minutes
	Sift to 150 microns

4. Results of change in decontamination of heavy metals in water

There is a wide range of processes for the determination of minerals in the sample, the method used in our project was electro-thermal atomic absorption spectrometry (ETAAS). This is a technique widely used to determine the metals present in a substance. Once the minerals are obtained, they are analyzed in order to obtain the chemical composition of the previously cleaned and dehydrated shell. In table 7, the concentrations of mercury, lead and cadmium that were used can be observed (Espinosa, 2019).
Then, the water was cleaned using 5 g of the grapefruit peel in 125 ml of water contaminated with mercury, lead and cadmium.

Table 7. Concentrations of Mercury, Lead and Cadmium

Concentrations of Mercury, Lead and Cadmium	
10ppm of mercury	60ppm of mercury
10ppm of lead and cadmium	60ppm of lead and cadmium
20ppm of mercury	70ppm of mercury
20ppm of lead and cadmium	70ppm of lead and cadmium
30ppm of mercury	80ppm of mercury
30ppm of lead and cadmium	80ppm of lead and cadmium
40ppm of mercury	90ppm of mercury
40ppm of lead and cadmium	90ppm of lead and cadmium
50ppm of mercury	100ppm of mercury
50ppm of lead and cadmium	100ppm of lead and cadmium

The results obtained in this process are satisfactory because mercury was reduced by up to 90%. In cadmium and lead, they did not show the same tendency as mercury. With these results, we can conclude that the grapefruit peel can be used as a filtering product that can purify water and be used for human consumption.
It is important to emphasize that this product complies with current trends that point towards the innovation of products that do not harm the environment, that is, that are ecological and friendly to the environment. The product that is being proposed based on grapefruit peel, has peculiarity, since Mexico is the 4th worldwide grapefruit producer. Our project complies with sustainable principles, since it is one hundred percent recyclable, and comes from waste of this fruit and organic that is proper to nature.

5. Conclusion

The problem of contamination heavy metal in Mexican waters is an alarming problem generating alternative methods to treat them. It is a very important task for researchers in our country, these methods must be sustainable as well as profitable. The application of Operational Excellence is a key factor to achieve the success of the project, since the application of the principles at each stage of the project, the results were as expected, complying with established dates for each stage of the project and the optimal use of the available technologies. We also increase the competitiveness of the method; the performance of each process was improved in each department and each team member always had a vision of continuous improvement.

At the end of our research project, we can conclude that the grapefruit peel contains certain specific characteristics, for example, pectic substances with the capacity to remove heavy toxic metals such as lead and mercury. According to the satisfactory results obtained, we can state that having accompanied the development of the project with the methodology of operational excellence provided us with tools to facilitate the success of the project, reducing costs, avoiding delays due to lack of effective communication or lack of planning. Also, by always having a vision beyond and always giving the best.

References

Comisión Nacional del Agua, (CONAGUA), https://www.gob.mx/conagua/articulos/calidad-del-agua?idiom=es, 15 de mayo de 2019

ATSDR, Department of Health and Human Services, Public Health Service, ATSDR. Toxicological Profile for Mercury. US Department of Health and Human Services, Atlanta, GA, USA, pp. 1–600. https://www.atsdr.cdc.gov/mercury/docs/11-229617-E-508_HealthEffects.pdf.

Garza-Reyes, J. A., I. Oraifige, H. Soriano-Meier, P. L. Forrester, and D. Harmanto, The Development of a Lean Park Homes Production Process Using Process Flow and Simulation Methods, *Journal of Manufacturing Technology Management*, vol.23, no.2, pp.178-197, 2012.

Seán, K., Understanding in multinational organizations, *Journal of Organizational Behavior*, vol.28, no.3, pp.303-325, 2007.

Kumar, S., Operational excellence for sustainability of Nepalese industries, *Procedia - Social and Behavioral Sciences*, vol.189, pp.458-464, 2015.

Bigelow, M., How to achive operationa excellence, *Quality Progress*, vol.35, no. 10, pp.70-75, 2002.

Shingo Institute. Utah. Shingo Model Handbook. Utah; 2013.p.9

Institute for Operational Excellence (IOE). What is Operational Excellence? Rhode Island; 2012

Miller, D., Raymer, J., Cook, R., Barker, S., The Shingo Model for Operational Excellence. Logan, Utah

Gleich, R., Sauter, R., Operational Excellence: Innovative Ansätze und Best Practices in der produzierenden Industrie (Innovative approaches and Best Practices in the production industry), München: Rudolf Haufe Verlag GmbH & Co. KG; 2008

Loera-Hernández, I, J and G. Espinosa-Garza, "Dehydration and Sieving to 150 Microns Process of Melon Seed", Defect and Diffusion Forum, Vol. 394, pp. 39-46, 2019

Espinosa, G, G., "Improving the Productivity of Avocado Seed for Create High Value Products", Defect and Diffusion Forum, Vol. 394, pp. 47-54, 2019

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 Sciences Director. She has published 1 patent and published more than 200 articles in journals and congress. She belongs to the National System of Researchers of Mexico.