PROJECT

Microplastic Removal

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Removal of Microplastics

Executive Summary

Ferrofluids are part of a new class of magnetic materials. These consist of colloidal magnetic nanoparticles dispersed and stabilized in a carrier liquid and that present magnetic and fluid properties, which is why they are of great technological importance [1]. Currently, among its applications [2] we can mention some such as magnetic seals in motors, lubricants in magnetic disks, instruments for optical memory and gyroscopes. Other applications are in magnetic instruments such as speakers, magnetic inks for bank checks, magnetic refrigeration units, etc. Ferrofluids also have applications in medicine as, for example, drug releasers, to restrict blood flow in certain parts of the body, and act as an opaque material for diagnostic imaging using X-rays or nuclear magnetic resonance. Ferrofluid stabilization is achieved by coating the magnetic particles with long-chain surfactant molecules, such as oleic acid, polyvinylamine, and double-layer surfactants [3]. The task of the surfactant is to produce the necessary entropic repulsion to overcome the strong magnetic attraction. In this project we propose the use of a home-made ferrofluid that is more friendly to the environment, for the removal of microplastics in a water sample, since the oil tends to join with the plastic because both present nonpolar covalent bonds, the substances do not polars tend to stick together; This is why cooking oil (oleic acid) and plastic particles unite, since both oil and microplastics are hydrocarbon chains and hydrocarbons are non-polar compounds. We add nanoparticles of magnetite to this mixture, mix and In this way, we obtain a more environmentally friendly ferrofluid since the iron particles also have non-polar bonds. Then, through the use of neodymium magnets, the iron + oil + microplastic particles are removed.

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1. Summary

Currently the existence of microplastics in different bodies of water is becoming a problem for the ecosystem of many species, including humans, for this reason we evaluated the efficiency of ferrofluid as a technology for the extraction of microplastics in water samples.

2. Introduction

According to the National Oceanic and Atmospheric Administration (NOAA) which defines a microplastic as one that is less than 5 mm long. Likewise, plastics are subject to degrade into smaller pieces, due to the effect of meteorological parameters, such as: precipitation, temperature, wind, humidity and solar radiation. This represents a large range of sizes; from objects that are easily visible to the naked eye to small particles or fibers that can only be seen with a high-quality microscope [2]. Of these materials, Pet is used in water and soda bottle containers and the cap of this container is generally made of polyethylene or polypropylene. These polymers float in both fresh and salt water, allowing them to travel long distances from the initial source of contamination. The presence of microplastics in the environment and in our food chain is a matter of growing concern as many marine species eat these microplastics, mistaking them for food; then we consume these marine species and we also incorporate these microplastics into our bodies. This has led many countries to increase testing for the presence of microplastics in a variety of samples, including bottled water, seawater and freshwater, leading in many countries to stricter legislation to limit the amount of plastics entering the ecosystem. Fourier transform infrared (FTIR) and Raman spectroscopies have been used for a long time for the analysis of polymers and, therefore, it is natural that they are currently the most widely used techniques to identify microplastics [3]. The visible light spectroscopy method is also widely used, although there are other ways that may be little used to perform the same task efficiently, such as counting by frames performing an image analysis by microscopy [4]; for which it is necessary to have microscopes that fulfill the function of capturing the images to be later analyzed by some imaging system. The most common method to remove microplastics is through 2 micron activated carbon filters or using the reverse osmosis system this will filter out the smallest microplastics known so far. Both systems have a relatively affordable cost, but currently new methods and systems have emerged for the removal of these microplastics, including the use of some variants of ferrofluid, which is a colloid that is highly polarizable in the presence of a magnetic field. The ferrofluid is made up of iron nanoparticles covered by a surfactant liquid that gives it liquid properties. In the presence of a magnetic field, the surface of this nanomaterial forms a very regular and pointed corrugated pattern, creating very diverse and dazzling shapes as the magnetic field moves around it.

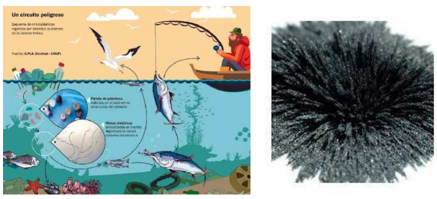

Fig. 1: food chain from microplastic to human and homemade ferrofluid

4. Objetives

- Obtain a more environmentally friendly ferrofluid with properties similar to commercial products.
- Carry out practical verification of the effectiveness of the use of a homemade ferrofluid for the extraction of microplastics in water samples.
- Evaluate which low-cost device will be used to visualize microplastics.

5. Materials and Methods

Next, the materials and methods that were used for the investigation and realization of this technological project are presented. The first part refers to the area of study and data collection; follows the description of what concerns the investigation of the technology involved to carry out the various processes for the extraction of microplastics and a last part that presents the methods used.

5.1 OBTAINING AND ANALYZING DATA

In all research work, the method used is very important, since the reliability and quality of the results achieved depend on its correct preparation and application. In our case, verify the efficiency of microplastic particle extraction using a homemade ferrofluid for which the The procedure was as follows: The initial process of research and data collection was through search engines in different languages and in a traditional way. After the collection of information and subsequent selection of relevant data using group discussions, questionnaires, data exchange through social networks and in person. In addition, in some instances we have advice from some researchers from the UBA (University of Buenos Aires, Ciudad Universitaria headquarters) on specific issues. The project worked as follows:

- Subjective: because it has tried to capture aspects of the evaluation of the access to the technological resource by the groups involved in the project in the statements and responses to closed and open questions generated by the working groups on issues of design, construction, materials , instruments and machinery to use.
- Objective: because part of the construction has been based on the review of online literature and on secondary data obtained from commercial companies existing in the current market, and on existing information on abundant but limited discontinued technology for its execution in the project.

Fig. 2: debating information at different times and spaces

6. ARCHEOLOGY OF THE PLASTIC PROBLEM AND ORIGIN OF FERROFLUID

Looking for information about plastic pollution in the oceans, we found that a few years ago there was a similar situation with another material that was used excessively, which was lead, since in 1923 lead began to be added to fuel the amount of this element increased dangerously until a lead regulation was introduced in 1970 [1]. But now it is the plastic that is beginning to be found in large concentrations in the water and although the lead could not be removed, the plastic can be removed. The origins of plastic take us back to 1860 and since then it has been very successful and we find it in all our daily lives, but the problem is that all these products derived from plastic end up as waste in the atmosphere and in various bodies of water. In the city of Buenos Aires, much of the plastic waste ends up in the stormwater whose final circuit is the Río de la Plata in the North or South Coast and finally in the Atlantic Ocean. The great concentrations of plastic in recent decades have come to create 5 islands made up entirely of plastic waste; These plastics by actions of nature and the environment (solar radiation, temperature, wind, etc.) are degrading into smaller pieces until they become micro plastics or nanoplastics. Regarding the ferrofluid, there are many controversies with the dates of creation, but the one that we consider most accurate is 1963, the date in which Stephen Papel patented his low-viscosity magnetic ferrofluid composed of kerosene + magnetite + oleic acid. The objective was to create fuel for rockets in the absence of gravity.

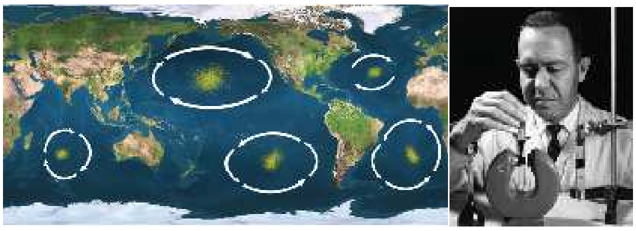

Fig. 3: Map of islands formed from plastic in the oceans, Stephen Papell inventor of ferrofluid

7. PROJECT DEVELOPMENT

The description, analysis and interpretation of the problem was used to evaluate the feasibility of using ferrofluid for the removal of microplastics. We first evaluated the use of commercial type ferrofluid to build a typical magnetic toy using it for the first tests. Ferrofluids are liquids that become polarized when exposed to a magnetic field and are made up of ferromagnetic particles suspended in a carrier fluid.

We practically evaluated how commercial ferrofluid behaves in a glass container under the effects of neodymium magnets, for which we used a glass bottle of a perfume that was given a previous treatment that consisted of filling it with hydrochloric acid and letting it rest 2 days; then the acid was extracted from its interior, it was rinsed well and it was placed in an oven at a temperature of 250º degrees for an approximate time of 1 hour, then the oven was turned off, allowing the jars to cool inside and then cleaning them with a product that allows the removal of impurities from its interior, then introducing a brine solution to finally place a few drops of commercial ferrofluid that we obtained from a donation from the company https://www.ferrotec.com/ inside the previously treated glass container that then it was covered and sealed with silicone, obtaining the following result.

Fig. 4: Commercial Ferrofluid Final Stage Perfume Bottle

The commercial ferrofluid is basically composed of petroleum, for this reason it could not be used in our experiment, since it would excessively contaminate the water when introduced, for this reason we evaluated a home-made ferrofluid through the oxidation of virulana and oleic acid. in this way it was more friendly with the environment, and from which we obtained very good results.

Fig. 5: Elements used in the first tests, result obtained

7.1 Evaluation of the device that will visualize microplastics

With the objective of simplifying the visualization of microplastics, we carried out some optical experiences to be able to do it, obviously the first thing we used was some magnifying glasses that we had at our disposal, depending on the sizes of microplastics they could be identified but by crushing them more it became difficult to identify them like taking pictures.

Fig. 6: Using various magnifying glasses to see microplastics

Another option was to use cell phones with different macro and divergent lenses, which were obtained from old cameras, laser pointer optics, peepholes, glass balls, and DVD and CD optics, which were adapted to cell phones by various methods. From printing Clips, elastic bands, hair clips, Eva rubber and wooden clothespins.

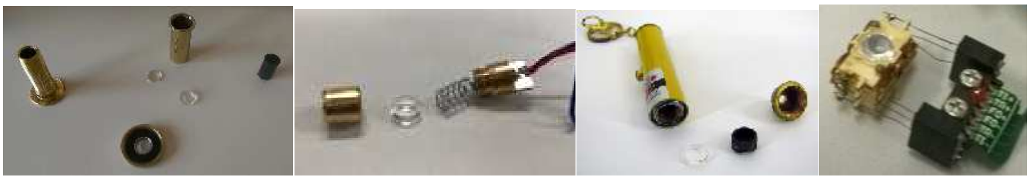

Fig.7: Unarmed Door Peephole, Unarmed Laser Pointers, CD Lens

The use of these lenses attached by different methods to a cell phone camera provide a good option, depending on the mega pixels of the CMOS that the cell phone has, a stable and well-defined image can be achieved from 100x to 250x.

Fig. 8: fix the lens on the cell phone

Another excellent option was to use the Web cameras to which we inverted their m12 optics with which they normally get about 400x to 600x, but to complete an aesthetic and functional device for our needs it would take us a lot of time, which we do not have.

Fig. 9: m12 optics, inverted lens webcam

As a final option, we decided to use USB microscopes, which are basically not microscopes but rather electronic magnifying glasses. With some modifications, we were able to increase their magnification to about 450x, which already allowed us to comfortably visualize microplastics and iron dust to later be able to obtain frames for further evaluation.

Fig. 10: using another USB microscope

The original support that USB microscopes come with is inefficient to take images of microplastic samples, for this reason we made a new USB microscope base design and printed it in PET-G material. https://www.youtube.com/shorts/Eios8T1fr-Q

Fig. 11: 3D printed parts, assembly of parts, assembled microscope, students using it

7.2 Producing microplastics

To produce the microplastic particles we used a Dremel drill with a wick that roughed up the bottles and their caps, we also used various types of files to carry out the same process, from a washing machine filter we obtained the plastic fibers.

Fig. 12: using drill and files to get microplastics plastic fibers

The samples of fiber, PET and PP microplastics were placed in different labeled containers for later use.

7.3 Carrying out the tests with oil and iron powder

We start by placing water next to the microplastics then we proceed to add the oleic acid (vegetable oil) which is of low density then we add half a teaspoon of nanoparticles of iron powder then we shake the container so that all the particles come together, and by passing some magnets inside a test tube, a ball of oil + microplastics + iron powder was formed which adheres to the glass test tube, finally we give two or three more passes of the magnet to remove traces of iron powder that may have remained and we pass the water to another container, it should be noted that the magnetization method can leave a minimum percentage of oil but it is easily removable by other methods.

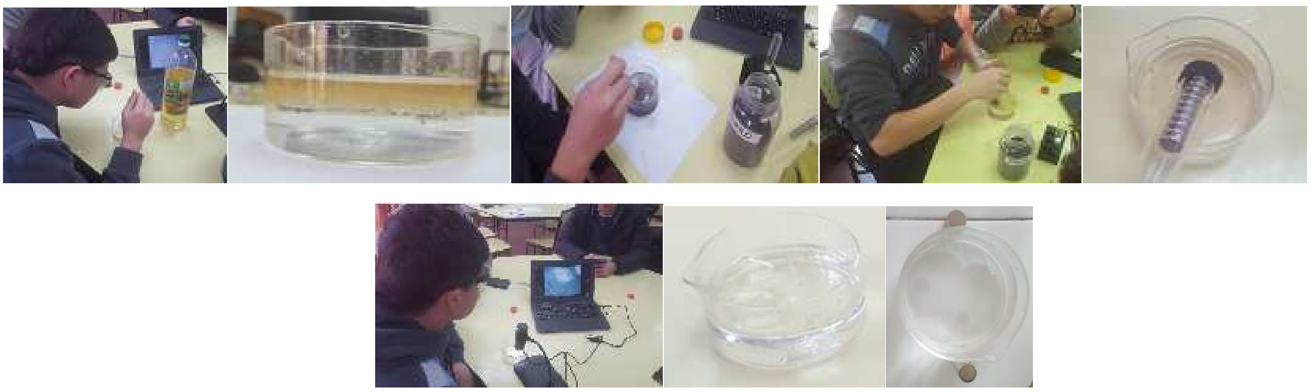

Fig. 13: microplastics and oil, placing iron powder and mixing, passing magnets, observing under a microscope, partial result, final result

7.4 Verifying the extraction process

To verify how good the microplastic removal system is, we photographed the samples through a USB microscope before and after using the ferrofluid removal system, then we introduced these images into the ImageJ program, which allows us to convert the images into color to a binary image, that is, in black or white bits, in this way we were able to know the percentage of black and white bits in the image, which will allow us to know the percentage of microplastics and water in the image.

Fig. 14: JPG color image, 8bit image, binarized image

After its transformation to a binary image we carry out a manual count of the microplastic particles in the first stages we use Paint and Photoshop then we use the imageJ program carrying out a manual count and finishing this practice we verify by means of an automatic count, the program also allows segmenting and place texts, numbers, scales etc.

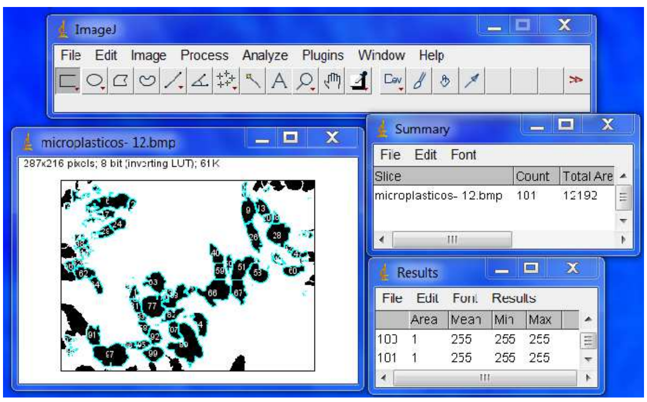

Fig.15: Microplastic particle count

8. RESULTS

To obtain the iron oxide particles we opted to burn virulana in this way it is possible to oxidize it and we manage to form iron oxide.

$$Fe + O_2 \rightarrow Fe_2O_3$$

Oxidación del hierro

Fig.16: burning virulana to obtain iron oxide

We practically verified that the commercial ferrofluid is a somewhat viscous black substance that stains both hands and different materials such as glass, fabrics, metal, etc., since it is made up of petroleum or its derivatives. The best way to clean the surfaces was using hydrochloric acid. Using powdered Vanish also gave good results. For this reason, the glass that will contain the commercial type ferrofluid must be previously treated to prevent it from staining when we introduce the commercial ferrofluid inside.

Fig. 17: Containers stained with commercial ferrofluid

We wanted to use the commercial ferrofluid as a binder that traps the microplastics, but this cannot be the case since the commercial type ferrofluid, due to its chemical composition, is very polluting and dirty and sticks to any surface if it does not have a previous treatment such as the one we do by heating the glass and letting it cool down since if we take it out of the oven it can burst or crack due to a difference in temperature, for this reason it cools down in the oven. Later we use Vanish to clean the glass containers. This step is essential to remove the impurities from the glass that have remained from the previous cleaning carried out. When using the Vanish, it must be remembered that an exothermic process occurs, so certain care must be taken when handling it.

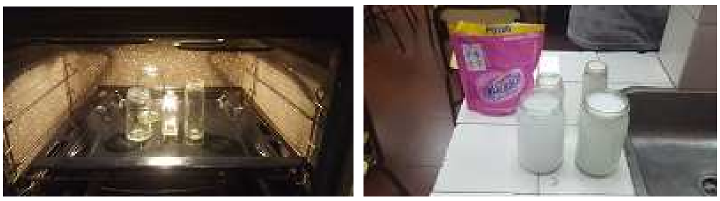

Fig.18: heating glass containers, cleaning with Vanish

We managed to experiment with various types of magnets and recreate experiences with both natural and artificial magnets. It was successfully possible to experiment with the commercial ferrofluid, ensuring that the ferrofluid does not adhere to the walls of the glass container, since all its impurities were eliminated by means of a previous treatment of the glass container, thanks to this we were able to build the classic game of ferrofluid. The elaboration of an excellent homemade ferrofluid with characteristics very similar to the commercial product was achieved using basic products such as virulana, oleic acid, distilled water, iron powder and salt.

Fig. 19: Homemade ferrofluid, homemade ferrofluid toy, commercial ferrofluid toy

We also evaluated other carrier fluids such as alcohol and different oleic acids using homemade ferrofluid for a more in-depth evaluation of their performance with this carrier fluid.

Fig. 20: homemade ferrofluid in oleic acid and with alcohol

The use of spectacle lenses, macro lenses, diverging plano-convex lenses and glass spheres among many options is feasible to be used as magnifying lenses for cell phone cameras is not a new idea, optically, but the small size of the housing Combined with the very high magnification that they provide when used in combination with a cell phone CMOS and inexpensive lenses makes this device practical but not for the specific use that we need.

Fig. 21: 3D of a clip model we designed, clip placed, clip alone, other system

To produce the microplastic particles, the best and most efficient method to grind it into smaller pieces was the use of a Dremel with a drill bit, thus achieving excellent results in bottle caps (PP), water bottles (PET), the Using the files manually took longer and did not give the same particle size as using the drill bits with the Dremel.

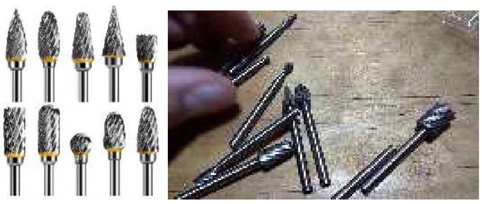

Fig. 22: some of the bits used

Oil tends to join plastics because they both have the same type of nonpolar bond and nonpolar substances tend to join that is why oil and plastic particles join since oil and plastic are hydrocarbon chains and these are non-polar chains, it is also the reason that water and oil do not mix since water has polar bonds.

Fig. 23: oleic acid and bonded microplastics

Iron also has nonpolar bonds so it also mixes with oil to form a colloidal suspension that does not mix with water. This magnetic or ferrofluid oil was first used by Dr. Arden Warner to clean up oil spills [9].

To obtain the iron dust particles, we use as a first option the discards from the workshop of the mechanics section. We then generate our own iron powder by using a grinder which grinds down an iron bar. We then sift the filings to separate the finer particles, then place them in a glass container with filtered water to clean the filings. In this way it was easy to remove the dirt from the filings, it was enough to shake the glass container while holding a neodymium magnet below. The dirt stays in the water and can be easily removed, we repeat this process 10 times.

Fig.24: obtaining iron particles, separating the smallest particles, washing the particles

It is very important that the granulometry of the iron powder is as small as possible so that it does not settle due to its weight, we were able to achieve this thanks to the use of a ball mill.

Several tests were carried out using different vegetable oleic acids and various particle sizes of iron powder and iron oxide. Observing practically that the corn and soybean oils gave the best results, but not the olive oil, the finer the granulometry of the iron powder, the better it would be adhered in suspension to the oleic acid since otherwise it would settle by its weight at the bottom. of the container.

Fig. 25: different granulometries of iron powder, decantation according to its granulometry, finer iron powder

For the magnetic removal of the ferrofluid, what gave us the best result was the use of 10x5 mm and 15x5mm neodymium magnets, which were placed inside glass test tubes since they lost magnetic power in plastic tubes.

Fig. 26: Plastic tubes and glass test tube, stirring ferrofluid, magnetic power of neodymium magnets

For a more efficient extraction of the ferrofluid, the different magnets that we had were rotated and made several passes over the sample, we also observed that if we couple several magnets we increase the final magnetic power.

We successfully achieved the observation of different sizes of microplastics through various technologies, magnifying glasses, modified cell phones, modified webcams, leaving us with the option of a low-cost USB microscope, which if we have to say that these devices are not microscopes, they are rather electronic magnifiers and do not reach the magnification they claim to have, but after the modifications made they served our purposes.

Fig. 27: USB microscope, some samples obtained

We also made observations of the generated iron dust and iron oxide as well as its size and microplastics and their fibers:

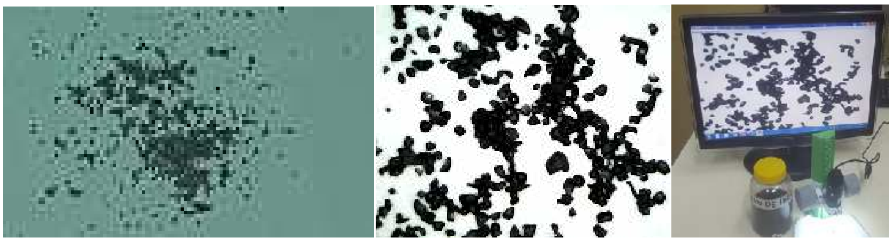

Fig. 28: iron powder various granulometries

The proposed verification method of the microplastic removal process was based on the particle count of images obtained by means of a USB microscope. Which in a first stage were transformed using an online software (https://convertio.co/es/jpg-rgb/) which transformed them into RGB images in this way the three red, green and blue channels are separated, and it selects the image with the desired nuclei, and a binary image is obtained (pixels have two possible values, 0 or 255); the binary image is modified to improve the separation of the nuclei and finally the count based on size and circularity was performed using basic software tools such as Paint and Photoshop; We then used ImageJ image processing software which greatly improved and speeded up the counting of microplastic particles. We performed a manual count using the Cell Counter (Plugins Cell Counter menu) and we also used automatic counting prior to image preparation.

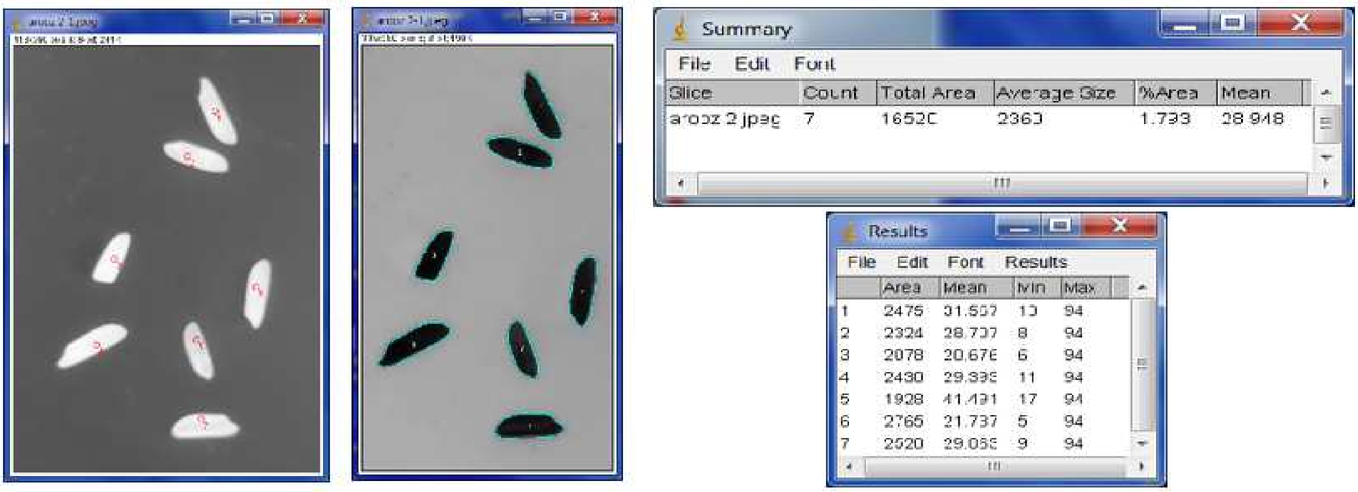

Fig. 29: Manual counting and automatic counting using pellets as samples

At the beginning and at the end of the tests we took frames of what was observed after reconstructing the images for counting with ImageJ these are some of the results

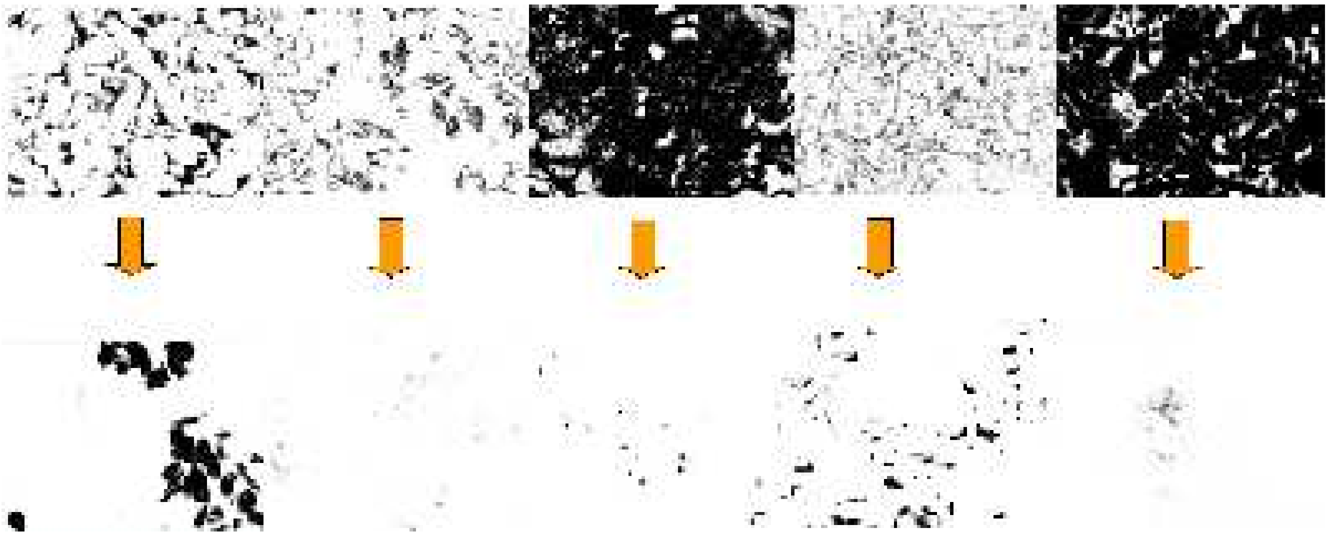

Fig. 30: images before and after the microplastic removal process with ferrofluid and using different methods

The results and percentages obtained through the imageJ software were transferred to a spreadsheet, we opted for Excel, we rounded the decimals for final analysis and preparation of the graphs with an approximate margin of ±2% in which we evaluated multiple samples.

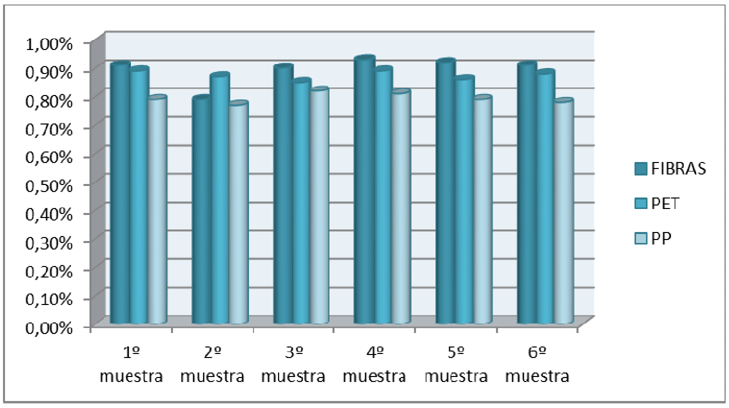

Fig. 31: graph with the data

9. DISCUSSION

The formula of the ferrofluid is patented although some components are not fully known and% but there are many recipes that can be used such as the one we apply generating iron oxide by burning virulana plus the addition of oleic acid or using iron powder the latter the finer the better result it will give.

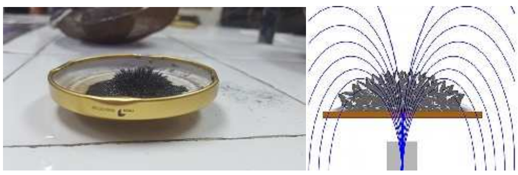

Fig. 32: homemade ferrofluid and neodymium magnet, scheme of the magnetic forces acting

The magnets we used were obtained from PC hard drives and other equipment that we managed to dismantle. In addition we acquired commercial magnets, we worked a little with some basic electromagnets using an iron core as a nail to which we gave a few turns of copper wire and then connected it to a cell or battery, but we did not obtain a strong magnetic field so we rule out its use.

Fig. 33: some used magnets

We practically experience that commercial ferrofluid is very polluting, for that reason we work on the preparation of a more environmentally friendly homemade ferrofluid, and we practically verified that the smaller the iron particles, the better the ferrofluid will work.

Fig. 34: virulana grating and sifting process

To keep all the particles together, oleic acid was used as a surfactant, thus achieving a paste with characteristics very similar to commercial ferrofluid but more environmentally friendly https://www.youtube.com/watch?v=8_HMEQj7j_c

Fig. 35: homemade ferrofluid

En general al momento de analizar muestras, un investigador debe realizar mediciones sobre el mismo, de modo de ponderar la muestra y agregar objetividad a sus observaciones. Para ello existe una amplia gama de herramientas de software, tanto comerciales como de código abierto; pero para trabajar en una imagen científica se requiere un programa científico, por eso nos decidimos por utilizar ImageJ el cual es un programa de procesamiento de imágenes diseñado para imágenes científicas, además es gratuito.

Fig. 36: imageJ software

Before carrying out the digital analysis of the images it is necessary to calibrate imageJ with a ruler. It is also essential to have photographs of a ruler that has some reference in bars or in grids of known distances in microns or cm and that is also captured with the same microscope, and has the same optical resolution as the photographs, size, width, and height. from image. It must be taken into account that when closing the imageJ program all the calibrations are lost, so when starting to use it, all the calibrations must be re-inserted.

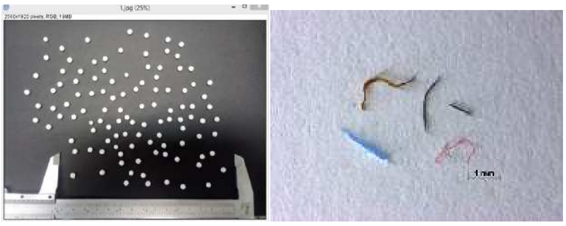

Fig. 37: Using caliper as a ruler, image with built-in scale

Nowadays pollution due to plastics is a global environmental problem. This situation has led many governments to create environmental policies that aim to manage the proper use of waste or recycling of said plastics. But as we practically demonstrate, recycling is not a solution since 100% of plastics are not recycled, therefore they will affect the environment, nature will try to eliminate it but it will only achieve in its process that it degrades into smaller pieces until it reaches to convert them into nanoplastics, which are currently already present in seawater, fresh water, sediments, soils and air. The presence of microplastics in these media makes their incorporation into the animal food chain very likely, which implies a feasible human exposure to microplastics. However, the current understanding of its effects can still be considered poor, due to the lack of further scientific studies on the subject of plastic ingestion. Detection of microplastics at these times is usually carried out by visual examination by light microscopy. With this project it was also possible to practically demonstrate that other less sophisticated methods can be used to detect certain sizes of microplastics. The methods that we use to carry out this project may not be conclusive since more validation of the tests should be carried out and more instruments should be used according to the method, such as a spectrophotometer or a more suitable optical device. It would be nice to try using stronger magnets and combining this method with a carbon filter, but for our demo purposes we considered them to be valid. We practically verified that ferrofluid is an excellent method for the extraction of certain types of microplastics. Despite being able to extract microplastics from water samples, we consider that plastic itself is a major environmental problem since scientists still do not know what to do with those microplastics extracted by any existing system to date. All this made us reconsider a bit what is traditionally styled to reduce the consumption of microplastics; the normal thing would be to say let's apply the 3 R's that is: reduce, recycle, reuse; but we think that this concept of the 3 Rs must be updated, for example: Recycle (reject single-use plastic and any plastic that is not needed), Reuse (choose products made to last longer instead of products with determined obsolescence, try to use the least amount of plastic elements possible) and Reduce (obviously that would be ideal but a world without plastic we do not believe that it can happen in the short or medium term). We would add to this reflect that today we live in a society that does not value used products enough, we would have to change that, we have to focus on services instead of replacements and we consider that another R would be needed, which would be to redesign; that is, on a larger scale we have to change our thinking from a linear take-use-dispose model to one that is more circular in nature in which we think of an end of life for a product. Likewise, thinking of a world without plastic is somewhat unrealistic, but perhaps managing to lower consumption or gradually using bioplastic may be a more feasible short-term solution.

10. CONCLUSIONS

- ✓ It was successfully managed to manipulate the commercial ferrofluid, and put together a small toy using this substance.
- ✓ We successfully managed to make a homemade ferrofluid with characteristics very similar to the commercial product, but with the advantage of being more environmentally friendly.
- ✓ Neodymium magnets are the best option to work with ferrofluid, although suction cup type electromagnets could also be used, which were not part of this project.
- ✓ Several feasible low-cost systems for the visualization of microplastics were evaluated and, depending on the scientific rigor of the research that is to be carried out, all of them could be used.
- ✓ We managed to improve a USB microscope in terms of its focus, we also improved its base through a new own design that we printed in 3D.
- ✓ For each type of plastic evaluated, the amount of microplastic removed was greater than 91% in plastic fibers, followed by PET with 87% and polypropylene with 80%, practically proving the effectiveness of the use of ferrofluids for the removal of certain types of microplastics.
- ✓ It is easily possible to scale with this method of removal but more tests would have to be carried out, which were not carried out in this project, to determine the optimal amount of ferrofluid to use per square meter and if its use in the sea as in other bodies is feasible. calmer waters or no waves.
- ✓ Although there are currently many tools or systems similar to the one presented in this project that allow the removal of microplastics, there is no technology to date that makes a safe elimination of 100% of these microplastic wastes since they could enter back to bodies of water. For this reason, we believe that the best thing would be to change our mentality towards plastic, since recycling as we experience is practically not a viable solution to this problem. A possible solution could perhaps be to incorporate bioplastic into our daily lives.

11. Bibliography

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