

The Disposal of Strippable Coatings Employed in Chemical and Radioactive Surface Decontamination

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Abstract—In general, to achieve surface decontamination large amounts of water are used as the main solvent in universal decontamination solutions. The used water, in order to be released in the stream flow, must be treated to eliminate the toxic substances. Strippable coatings visibly minimize the amount of waste resulting from the decontamination process. Biodegradable films based on polyvinyl alcohol were synthesized and used within this study. The polymeric coatings also contains Bentonite nano-clay (BT) that is a rheological agent, a complexing agent used to entrap the heavy metal or radioactive particles and glycerol used as an additive to give the films the proper mechanical properties. Nevertheless, the used coatings must also be disposed of in a certain way. This paper studies few methods in which strippable coatings that are presented as chemical and/or radioactive waste are treated and proposes means to reutilize used films that are or/are not contaminated, but also suggests a simplified technological process for producing such decontamination solutions.

Index Terms—biodegradable, decontamination, heavy metals, radioactive waste, strippable coating.

I. INTRODUCTION

Chemical and radioactive decontamination is imperative to perform if an accident has occurred which resulted in toxic materials and contaminated buildings and tactical spaces can no longer be used. The cost of surfaces decontamination is quite high, but especially in the case of radioisotopes decontamination which requires special treatment of radioactive waste [1]. The decontamination technique presented in this paper is based on the use of strippable coatings that are suitable for surface decontamination, which can also significantly reduce the waste volume.

II. MATERIALS AND METHODS

The method through which the decontamination solutions were synthesized at laboratory scale is represented in Fig. 1. The solutions were made in batches of 100 mg each. In the first phase, 0.5 g of complexing agent is added over 83.5 ml of distilled and solubilized under magnetic stirring.

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The complexing agent may vary, although the following showed similar decontamination factors for removing radioactive materials: EDTA (ethylenediaminetetraacetic acid), DTPA (Diethylenetriaminepentaacetic acid, pentasodium salt), IDS (Iminodisuccinic acid), Catechol (1,2-dihydroxybenzene), PBTC (2-Phosphonobutane-1,2,4-tricarboxylic acid), EDDS (Ethylenediamine-N,N0 -disuccinic acid trisodium salt solution) and Gallic Acid (Pulpea, 2020). The second step consists in adding 1 g of nanoclay (Bentonite) and stirring it for 24 hours. Then, in the next stage, the temperature is raised to 100°C and 10 g of PVA (polyvinyl alcohol) is solubilized. In the last stage, the fourth, the heating program of the solution is turned off and 5 g of glycerol is added and mixed in. The solution is allowed to cool, poured into plastic containers and kept in a dry-cool place away from the sun, until it needs to be applied.

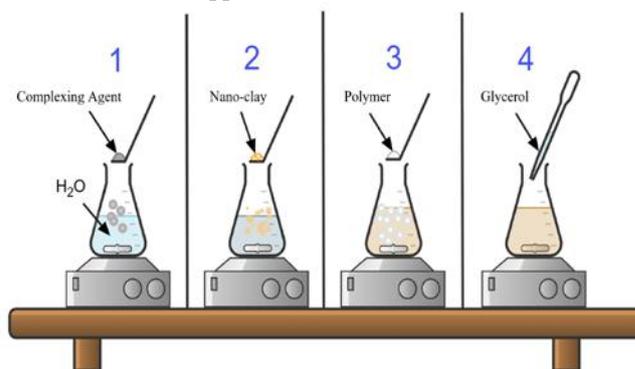


Figure 1. Laboratory installation representation

III. NECESSARY STEPS FOR INDUSTRIAL MANUFACTURING

The objective of the technological manufacturing process, in addition to synthesize the solution, is to make the procedure as simple as it could be. It needs to not involve toxic substances that affect the health of the military personnel that will apply it, to use minimal resources (electricity) so that the process is environmentally friendly and can be automatized to allow mass production of the decontamination material. However, the actual manufacture process of the solution involves several steps represented in Fig. 2, such as:

- ✓Preparation of raw material
- ✓Preparation of the decontamination solution
- ✓Loading and packaging of the final product

For the elaboration of the technological process and of the installation at industrial scale, initial actions have been completed. Preliminary research of raw materials and laboratory research of how to make the decontamination solutions were studied and then a model on small-scale industrial production of decontamination solutions was

suggested through establishing the technological scheme and material flow of the entire process.

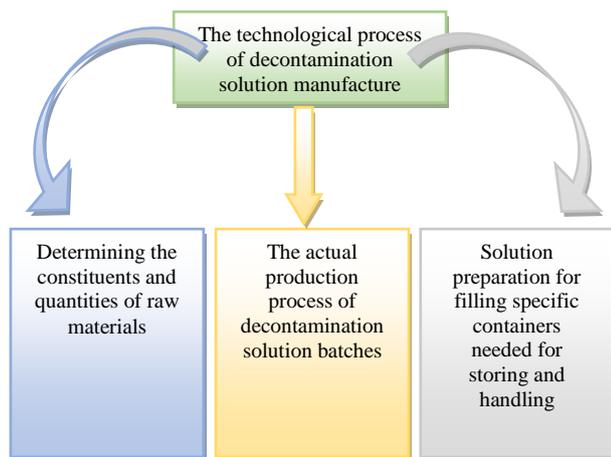


Figure 2. Global scheme of the decontamination solution manufacturing process

A. Reception and preparation of raw materials

The chemical agents used in the making of the decontamination solution can be in liquid or solid form, but also as fine nanoparticles (bentonite and saponite). The state of aggregation of the substances is necessary for identifying the means of their penetration into the body during their handling, following which staff protection measures are established.

In addition to the effects of raw materials on the human body, their effects on the environment must also be known.

The reception of base materials is done by examining their appearance as well as the packaging, the verification of the quality certification, after that they are stored in a well-established place, depending on the toxicity and the class of risk of which they are associated with, until they are utilized.

However, because the feedstock has low toxicity and high biodegradability they do not require additional, high-priced protection measures in case of storage or handling.

The preparation of the materials for obtaining the decontaminating mixture batches is done by removing them from the storage, weighing each component and loading the reactor dosing containers. Depending on the situation, leakage of liquids and aerosolization of nanoparticles shall be avoided during the manipulation process.

B. The process of preparing the decontamination solution

The study of the industrial manufacturing process of the decontamination solution starts from the description of the laboratory installation presented in Fig. 1, this being a simplified version in which smaller quantities of substances are used. The first batches that are produced in limited amounts are necessary for the characterization and testing of the material. The industrial manufacture process of the product requires a known sequence of technological operations through which the raw materials are transformed into the decontamination solution. These operations and steps are described by a technological flow shown in Fig. 3.

Starting from the laboratory solution preparation, installation model (Fig. 1), a schematically industrial method for synthesis the decontamination solution,

described in Fig. 4, is considered. Therefore, five dispensers are needed for the feedstock dosing, a reactor equipped with a stirrer (an emulsifier is recommended to reduce the production time) and a tank with degassing devices, that also has the possibility to dose the decontamination solution into the predetermined packaging.

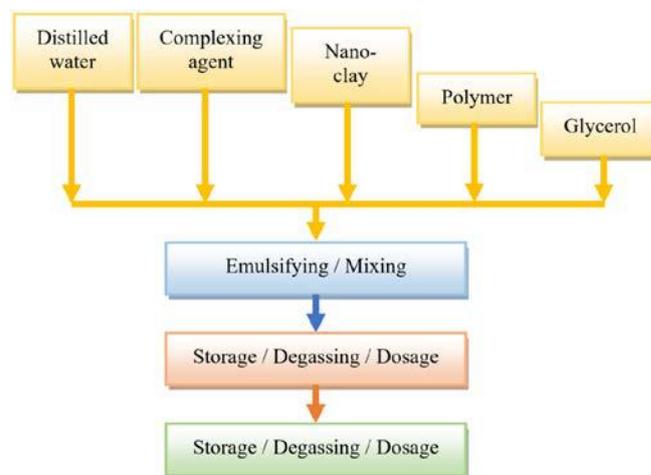


Figure 3. Technological flow of the manufacturing process

According to the laboratory model, the following manufacturing technology was proposed represented in Fig. 4 and the terms used are described in Table I.

TABLE I. TERMS DESCRIPTION

Name	Description
D1	Distilled water dispenser
D2	Complexing agent dispenser
D3	Nano-clay dispenser
D4	Polymer dispenser
D5	Glycerol dispenser
V1-V9	Pipe valve
R1	Reactor with heating jacket
R2	Degassing tank
R3	Packaging / transport and storage container
BT	Conveyor belt

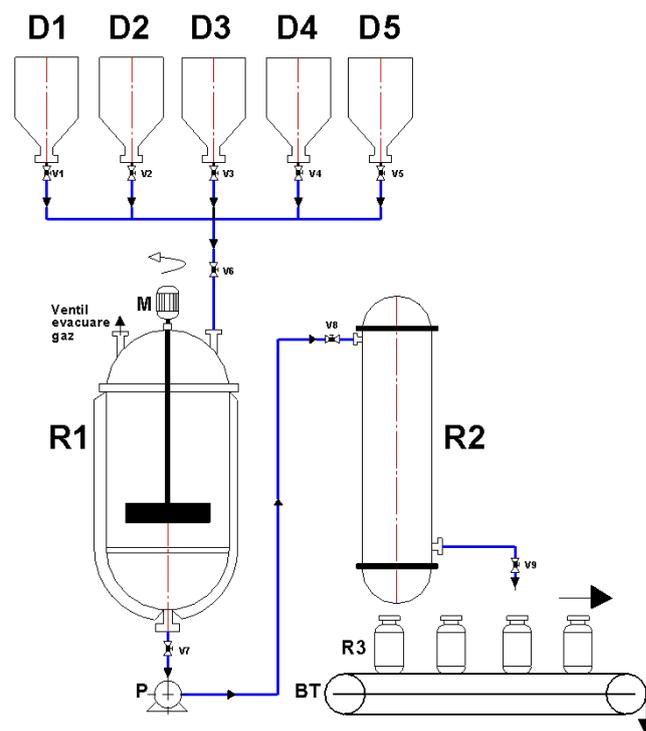


Figure 4. Industrial decontamination solution manufacturing technology

After the qualitative and quantitative reception of the feedstock needed to carry out the batches of polymeric decontamination solution, the materials are weighed and the packaging is checked so that the substances have not exceeded the expiry date and their characteristics are in accordance with the requirements.

To make batches of 100 kg of decontamination solution, for the first step the tap is opened to dose 83.5 l of distilled water in the reactor that is equipped with a heating jacket, emulsifier (high-speed stirrer) / stirrer, thermometer and local ventilation. For the second step, 0.5 kg of complexing agent (one of those indicated above) is added after the water and stirring / emulsification is started. After 1 h of mixing the complexing agent is solubilized. Then 1 kg of nanoclay can be added (Bentonite / Saponite) which, can be stirred for 24 hours with a normal stirrer or only 1 hour if high speed stirring (emulsifier) is used. After clay nanoparticles emulsification and hydration, the mixture is heated to 100°C, and 10 kg of polyvinyl alcohol is dosed in the reactor and it is stirred for another 4 hours. In the final stage, the heating is stopped and 5 kg of anhydrous glycerin added and then stirred for another hour. The final mixture is then introduced into a tank with a degassing system where is stored and prepared for the packaging.

IV. LARGE AREAS DECONTAMINATION PROCESS

The decontamination activity using strippable coatings is relatively simple to implement and an operator can be easily trained to use the decontamination solution. Given that the composite films are effective at a thickness between 0.1 and 0.4 mm, it is necessary a quantity between 0.75 and 3 kg to cover and thus decontaminate an area of 1 m².

In Fig. 5, 6 and 7 it can be observed the implementation of this procedure in practice on a delimited surface of 0.81 m².



Figure 5. Pouring the decontamination solution over a specific area

The solution was poured and left to disperse on the surface, without intervening with a brush for uniformity, to observe its behaviour without the influence of mechanical procedures. Then, the decontamination solution was allowed to dry for 24 hours and after polymeric film formation this it was peeled off as seen in Fig. 6.



Figure 6. Peeling off the strippable coating from the surface

After peeling 125 g of polymeric film resulted from the procedure, representing the amount of waste (Fig. 7) obtained from approximately 450 g of decontamination solution.



Figure 7. Solid waste resulting from the decontamination procedure

By representing and scaling the surface in Solidworks software application, represented in Fig. 8, the approximate area was determined with a size of 0.474 ± 0.05 m² formed by pouring 450 g of decontamination solution at a variation of the polymeric film thickness between 0.1 and 0.4 mm, representing approximately 60% of the marked surface (90×90 cm).

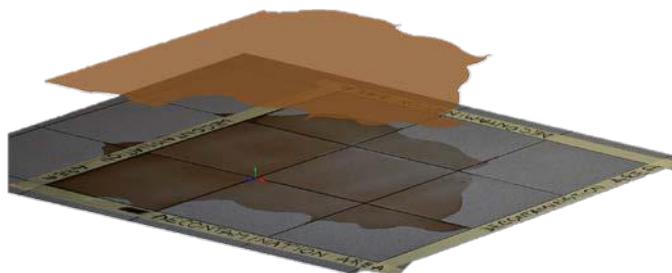


Figure 8. Determination of the size of the decontaminated surface

V. RESULTING WASTE TREATMENT

Decontamination films are formed by applying the polymeric solution to a surface by pouring and brushing or spraying then let it dry for 24 h. During application, the active materials within the solution, such as complexing agent and clay nanoparticles, migrate into the surface micro-cracks and come into direct contact with the contaminant. During the period when the solution is still liquid, the attraction, adsorption and even chemical binding of the active components of the solution to the toxic material placed on the surface takes place. During the drying process, the contaminant is mechanically fixed in the polymer matrix. After the film is formed, it is removed by peeling off the surface, which is now decontaminated. Surface contamination is removed at the same time with the strippable coating and a solid, dry residue is produced that no longer generates toxic aerosols. Water-based polymeric films are designed for decontamination of smooth and semi-porous surfaces such as steel, concrete, aluminum, plastic, wood and painted surfaces [2]. The typical amount of decontamination solution needed is between 0.7 – 3 l/m² and most films are cured after 4 – 24 hours of drying, depending greatly on temperature and humidity [3]. Some of the films can detect uranium and plutonium by visual colour change [4]. However, the polymeric films can be used in two ways, by their application after the contamination has taken place, or by their preventive application, before the contamination.

All decontamination techniques involve the subsequent treatment of waste obtained from this process. Common techniques based on excessive water are used for decontamination in combination with various surfactants and complexing agents, involve capturing this wastewater and treating it to remove any toxic substances so that it can be discharged into the sewer system. Compared to this process, decontamination using polymer films significantly reduces the volume of waste, but it still needs treatment. Thus, depending on the type of agent that has been decontaminated, whether it was heavy metals or radioactive materials, different methods of treatment, removal or storage of the resulting waste from decontamination using composite polymeric films have been proposed. The treatment modalities of radioactive or non-radioactive waste resulting from the decontamination process are presented in Fig. 9.



Figure 9. Waste treatment methods

Incineration uses very high temperatures to oxidize toxic waste. The main objective of incineration, especially for radioactive waste, is to reduce the volume of the residue, as most contaminated items are large items such as clothes, wood and plastics. However, incineration does not eliminate metals or radioactive materials. In general, incinerators for radioactive materials are equipped with high-efficiency filters, which can capture most radionuclides, but very small particles (a small part of the total toxic waste) cannot be retained. The escaping fraction, however, tends to be in the form of aerosols that are more easily absorbed by living organisms than larger particles.

Incinerators, like many combustion devices, convert combustible materials, mainly into carbon dioxide and water (steam). However, in general, it also creates toxic by-products, known as “incomplete combustion products” or (ICP). These products may be more toxic than the initial waste. The total amount and toxicity of PIC in incinerators are extremely uncertain [6]. The most studied toxic PIC are known as dioxins. The ones presented above and similar toxic chemicals accumulate in the fatty tissue, increasing in concentration at each successive level of the food chain. Until 1993, regulations did not consider this factor. Although special filters can reduce toxic emissions well below legal limits, they still concentrate toxins in the form of ash. In addition, in most cases contaminated ash and filters pose a greater danger to the environment than the initial toxic materials that have been incinerated [7]. However, the permanent storage of ash in well-monitored structures can reduce the risk of groundwater contamination and there are alternatives to incineration that uses low temperature treatment of waste, which affect the environment to a lesser extent, such as electrochemical oxidation, wet oxidation, plasma oxidation and photocatalytic oxidation [2].

Therefore, incineration can be one of the ways in which decontamination films can be treated to further reduce the volume of waste resulting from the decontamination process.

Precipitation processes have been developed for analytical chemistry applications for almost all radioactive elements and heavy metals. Precipitation is not a preferred method for the industrial treatment of contaminated materials, as it usually requires separate precipitation (batch) of each element and also solid-liquid separation operations after each precipitation step. These processes produce large volumes of waste, without being able to achieve very high separation factors [8].

The precipitation of actinides was achieved almost 50 years ago using BiPO_4 by the process of co-precipitation of Pu and Np [9]. This process does not quantitatively remove any element due to solubility limitations and precipitates other metals, such as zirconium, which form insoluble phosphates. Oxalates of Pu, Np and Am are relatively insoluble in HNO_3 at a concentration of 1 M. However, there are always several precipitation steps to be able to comply with the limits for carcinogens and toxic materials permitted by law. Strontium can be precipitated in alkaline carbonate solutions and, under certain conditions, in hydroxide or weakly acidic solutions by the addition of sulfate ions. Strontium precipitates are all soluble and require several steps of precipitation to achieve a high separation factor. Numerous precipitation processes have also been found for caesium in which phosphatungstic acid, ammonium phosphomolybdate and ammonium phosphotungstate are used for acidic solutions, as well as sodium tetraphenylborate and nickel hexacyanoferrates for alkaline solutions. With the exception of the process involving tetraphenylborate, capable of decontamination factors of up to 10^4 , cesium precipitation processes would also require several steps [2].

Decontamination films are soluble in water, therefore, to investigate the phenomenon and to determine the time required for their total solubility, a solubilization process was performed in an amount of water equal to the amount lost by the formation of solid films. The solubilization process shows step by step in Fig. 10.

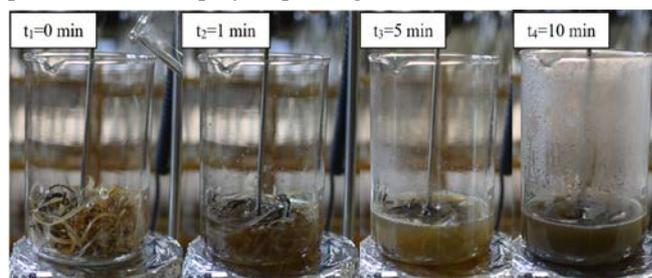


Figure 10. The film solubilization process

Even if the precipitation of heavy metals and radioactive materials is possible in the case of decontamination films, this is a difficult process, requiring multiple stages, toxic reactants and generating large volumes of liquid waste.

The management and storage of low level radioactive waste (LLW) are carried out in specially designed units. Most waste is generated from nuclear research and nuclear applications, in the medical, biological, agricultural industry but also in construction. In radioactive waste processing plants, the waste is selected and processed according to their physical and radiological properties. The decomposition products are stored in an area intended for radionuclides with short half-life. Radioactive sources with long half-lives are immobilized by various methods. In general, liquid radioactive waste resulting from decontamination is treated

by filtration or chemical precipitation, and the result, such as radioactive viscous precipitation or solid particles resulting from filtration, is immobilized by cementation. Solid waste is compacted into a cylindrical shape to reduce its size [10].

In the case of strippable coatings, two different methods of incorporating film-forming waste that did not give good performance were studied. For the first one, it is desired to incorporate polymeric films in the form of strips in plaster blocks. There were made 3 types of mixtures in which the amount of plaster (400 g) and water (200 ml) were kept constant, and the amount of film varied between 0 g, 10 g and 20 g. Strips of polymeric films were mixed with plaster, the mixture was sprinkled over water and stirred for 30 s. The composition was poured into molds, after 2 h it was stripped and after 7 days the compression and bending test were performed and the representative graphs are indicated in Fig. 11.

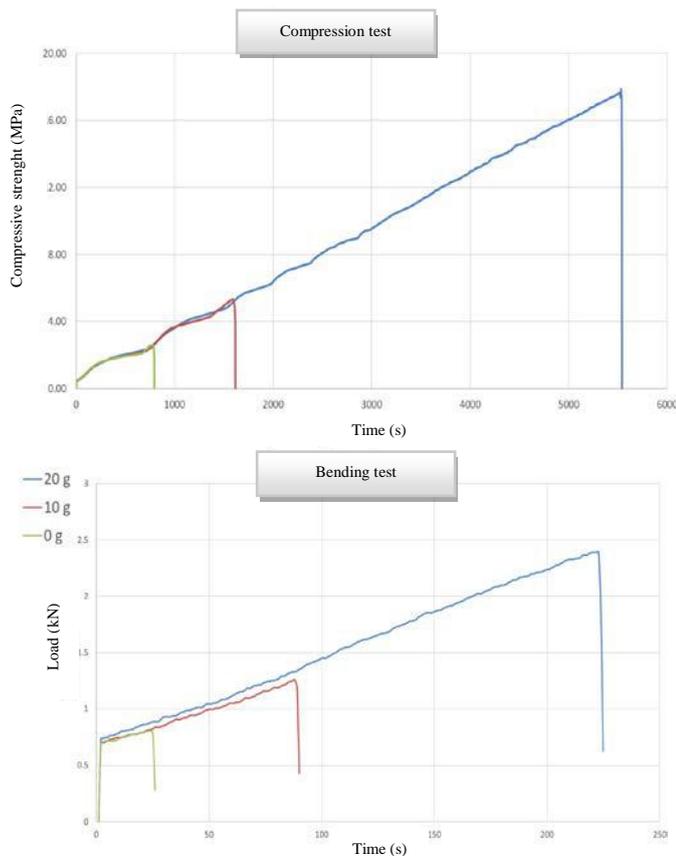


Figure 11. Graphical representation of compression and bending tests

The appearance of the materials before and after bending testing is displayed in Fig. 12. Following the tests performed on the plaster blocks, it was determined that the insertion of the strippable coatings in such materials decreases their mechanical properties and the polymer films storing in this way is not a viable solution.

Then, an attempt was made to immobilize the radioactive material by embedding the polymeric solution that includes the toxic material in cement. Two recipes were considered for this mixture, one containing 550 g of polymeric solution and without a solution that was replaced with water. The amount of cement (950 g) and gravel were kept the same. In this case, Fig. 13 shows that after 24 hours from pouring the mixtures, the block that does not contain the polymer solution dried, but the other did not form even after this time, due to the fact that this solution retains moisture and does not allow the composition to dry.

VI. CONCLUSIONS

This paper presented three aspects: the development of a technology for manufacturing the decontamination solution at the industrial level, the description of the practical use of the solution (and thus the strippable coatings) and the establishment of methods for treating the resulting toxic waste from the decontamination process.

The manufacturing technology of such a solution is a simple one with low consumption of resources and equipment. It does not require additional materials apart from the main components, and the process takes place at low temperatures without the release of by-products. Usually, the technology of using, applying the solution and also of peeling the strippable coatings is not complicated, and the training of the operating personnel is minimal.

The treatment of film-forming waste resulting from decontamination activities must be carried out in concordance with the toxic material contained within and in accordance with the regulations in force.

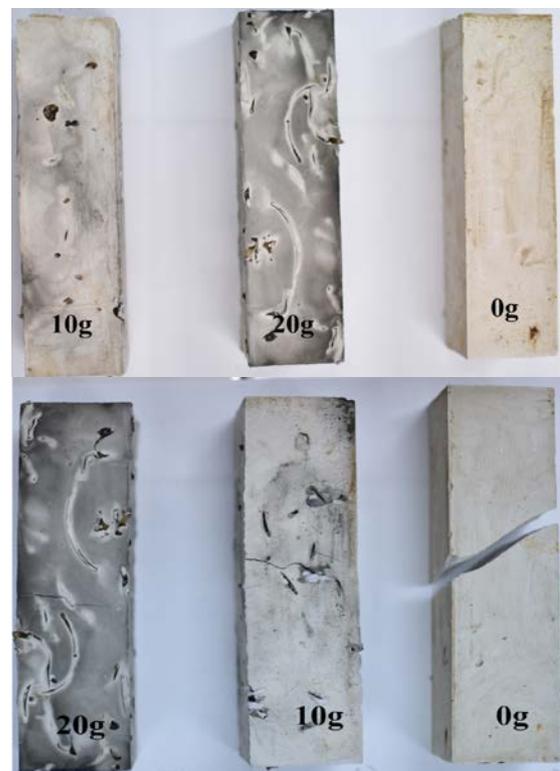


Figure 12. Representation of the sample before and after bending test



Figure 13. Representation of the sample before and after drying

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