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# IMPACT OF INDUSTRIAL AGENTS ON PVC MATERIAL

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***Abstract:*** *This study analyzes the influence of industrial factors on polyvinyl chloride material, focusing on mechanical and elastic changes caused by different test environments. on polyvinyl chloride material is widely used due to its low cost and versatile chemical properties, but exposure to various environmental factors can significantly affect its performance. In the research, on polyvinyl chloride specimens were tested by uniaxial tensile testing after exposure to distilled water, cooling oil, saline, and ultraviolet radiation type C. The samples were immersed in liquid during the 24 hours, followed by mechanical testing according to ISO 527-2 and ISO 62:2008. The results showed that distilled water and cooling oil resulted in an increase in the maximum stress supported, while ultraviolet radiation type C and saline caused a significant reduction in mechanical strength. Statistical analysis performed with Minitab 18 confirmed the normal distribution of the data and allowed the identification of outliers. The study highlights the need to select materials according to the conditions of use, preventing premature degradation of on polyvinyl chloride components in aggressive industrial environments.*

***Keywords:*** *Polyvinyl chloride, liquid absorption, mechanical characteristics, tensile tests*

## 1. INTRODUCTION

Polymeric materials are essential in a wide range of industrial applications, including automotive, aeronautics, biomedical, and electronics, due to their favorable weight-to-strength ratio, easy processability, and low cost. However, their interaction with environmental factors causes structural and functional changes that can compromise their performance [1]. Recent studies in the field of materials science and mechanical engineering are based on the impact of environmental factors such as temperature, humidity, UV radiation, and exposure to various chemicals on the mechanical and elastic properties of polymers. In this context, a detailed analysis of these influences is essential for the development of materials with increased durability, but also for their applicability in the required industry [2].

The six most used polymers who account almost 98% of all plastics materials encountered in everyday life are: polyethylene (PE), polypropylene (PP), polyvinyl chloride (PVC), polyethylene terephthalate (PET), polystyrene (PS) and polycarbonate (PC). [3]. Each of these polymers has specific degradation modes and different degrees of resistance to "heat, light and different chemicals. Polyethylene and polypropylene are sensitive to oxidation and UV radiation, while PVC can discolor at high temperatures and become very brittle" [4]. PET is "sensitive to hydrolysis and attack by strong acids, while polycarbonate decomposes rapidly when exposed to strong bases". Polymers obtained by step polymerization "are degraded by specific chemicals such as strong acids and bases" [5]. They are made by "condensation polymerization, so degradation is a reversal of the synthesis reaction. Other degradation mechanisms include interaction with strong oxidizing agents and exposure to UV radiation" [6].

Water adsorption, a key element in the present study, is also addressed in various studies as an environmental factor that modifies the mechanical and elastic behavior of polymers, especially the behavior of thermoplastics. For example, polyamide 6 (PA6) has a high water absorption according to [7], which leads to a considerable decrease in material stiffness. The study [8] analyzes the degradation of the mechanical properties of polymer nanocomposites exposed to liquid media, highlighting the impact of water, organic solvents and detergents on these materials. Water acts as a plasticizer, reducing mechanical strength, while aggressive liquids, accelerate cracking [9].

UV radiation is another important factor in polymer degradation and frequently studied in the literature [10]. UV light is part of the electromagnetic spectrum, having a higher energy than visible light, but lower than x and γ rays. Absorption of UV radiation by plastics can cause photons to be energized, leading to the formation of free radicals. Although pure polymers "do not typically absorb UV radiation, the presence of impurities and catalytic residues facilitates this process" [11].

Polymers such as polyethylene (PE), polypropylene (PP), polyvinyl chloride (PVC) and polycarbonate (PC) show different sensitivities to radiation depending on their chemical structure [12]. In the case of polyethylene and polypropylene, cross-linking predominates at low doses, while oxidative degradation predominates at high doses. PVC is very sensitive, developing structural changes and loss of thermal stability in the presence of radiation [13]. Polycarbonate and aromatic polymers tend to have higher radiation resistance due to their stable chemical structure [14]. UV degradation effects are mainly at the surface of the material and rarely penetrate deeper than 0.5 mm. For materials exposed to direct sunlight, it is essential that engineers and designers set appropriate testing standards and use polymers formulated for long-term resistance [15]. Protection can be provided by adding additives to the molten polymer or by mixing them directly into the resin. Pigments, such as carbon black at about 2%, provide protection by blocking UV radiation, and titanium dioxide can also be effective in reducing degradation of sun-exposed polymers [3].

Polyvinyl chloride (PVC) is a widely used plastic, in view of its low cost but also because of its multiple physic-chemical characteristics (Figure 1) [16]. PVC, a thermoplastic polymer created by polymerization of vinyl chloride, has a chemical structure that offers the possibility to change properties with additives and plasticizers. PVC is used in both rigid and flexible applications for this reason. PVC has a chemical structure that makes it inert when in contact with many common chemicals, such as dilute acids, bases, and weak organic solvents. However, it is susceptible to assault by liquid chlorine or acetonitrile, which are potent oxidizing agents. Due to its significant resistance to flame propagation, it is appropriate for numerous scenarios requiring elevated fire safety standards. [17].

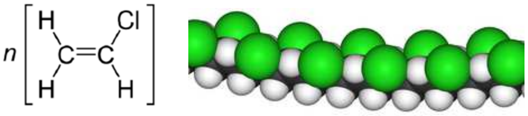

**Fig. 1.** Chemical formula of PVC and a 3D view of the chemical chain [18]

## 2. MATERIALS AND METHOD

The mechanical characterization of polymeric materials elaborated by different manufacturing technologies is of great interest among researchers, given that the way they are obtained can influence the performance of products made from these materials. The aim of the present study is to determine the mechanical and elastic characteristics of polyvinyl chloride (PVC) maintained in various environments: ambient environment, distilled water, cooling oil, saline solution, and UV-C radiation by uniaxial tensile testing. The results thus obtained will enable comparative studies to be carried out to determine the relationships between the characteristics of the working environment and the mechanical and elastic characteristics of the PVC material. Given the specificity of the material used in this study, it was decided that the specimens for tensile testing would be cut from extruded semi-finished products in sheet form, using water jet cutting technology. The laser cutting method was considered unviable because of the risk of self-ignition of the material. Also, cutting using mechanical processing by milling was not considered, as there is a possibility of local (along with the contour of the specimens) modification of the mechanical characteristics of the tested materials due to local heating of the material during processing. At the same time, cutting by stamping would have produced significant burrs due to the high elongation coefficient characteristic of some of the materials studied [19].

The shape and dimensions of the specimens used are shown in Figure 2, according to ISO 527-2: Tensile Testing for Plastics, 2012 [20], which governs the uniaxial tensile testing of plastic materials.

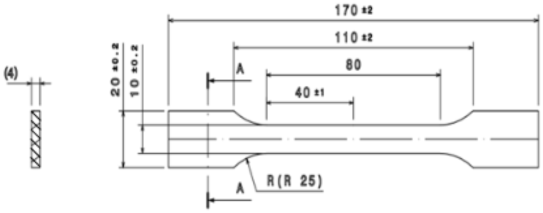

**Fig. 2.** PVC specimen dimensions (in mm) [20]

After the water jet flow, all specimens were subjected to quality control, in which their dimensions were measured with a digital caliper with an accuracy of 0.01 mm. Thus, the specimens were validated before testing, both in terms of construction and dimensions. The specimens intended for immersion in the above-mentioned liquid media were also weighed using a high-precision weighing scale to determine the degree of absorption of the liquid into the material. After making the specimens, we realized a test method using GraphWork software, which is equipped on the Galdabini testing machine, model Quasar 25. In this method, we defined the geometrical dimensions of the specimens and the speed test (5 mm/min, according to the standards). This test method also specified the quantities to be determined (recorded) from the tests carried out: force (N), elongation (mm), engineering stress (MPa), and engineering strain.

To ensure the best possible positioning and orientation of the specimens in the testing machine grips, as well as to achieve coaxially with the vertical axes of the machine grips and consistent specimen placement between the grips, a specimen orientation device was designed, realized, and used (Figure 3). This device was essential to position the specimen axis coinciding with the central axis of the testing machine grips, thus reducing the possibility of eccentric stretching stresses on the specimen, which would have led to additional bending stresses that could have negatively influenced the test results. It should be noted that the device used for specimen positioning and orientation was 3D printed and did not influence the experimental results in any way, because after the specimen was correctly aligned with the grips, this device has been removed.

**Fig 3.** Test specimen attached to the test machine using the device for positioning and orientation

In the case of specimens immersed in distilled water, cooling oil, or saline solution, they were first dried in an oven at 500 °C for 24 h according to ISO 62:2008 Plastics: Determination of Water Absorption [21]. After removal from the oven, the test specimens were weighed and then immersed in the above-mentioned mediums for 24 h. Uniaxial tensile testing conducted under controlled laboratory conditions plays a crucial role in the study and characterization of polymeric materials. These tests primarily facilitate the evaluation of key mechanical properties, enabling comparative analyses across different environmental conditions [22].

The second environment analyzed was distilled water, provided by Simple Quality Products, used specifically to immerse test samples. This type of distilled water finds multiple industrial applications, including dilution agents for windshield cleaning fluids and antifreeze, electrolyte replenishment in batteries, ironing sprays, and internal combustion engine cooling systems. The water employed in this study presented a pH range of 6 to 7.5 and a density of 1 g/cm³ at a temperature of 20°C.

A third testing environment included cooling oil, specifically Azur-Cut brand 602.01 M-15. This oil comprises mineral oil combined with special additives designed to withstand high-pressure environments typically encountered in heavy-duty machining operations. Featuring a viscosity of 15 mm²/s at 40°C, this synthetic oil serves industrial machining processes where efficient cooling and lubrication are essential.

The fourth testing medium involved exposure to ultraviolet type C (UV-C) radiation. Evaluating polymers under UV-C exposure is necessary for understanding their resistance and durability when subjected to intense ultraviolet irradiation. UV-C radiation, characterized by wavelengths ranging from 100 to 280 nanometers, is particularly aggressive in inducing photochemical degradation processes in polymeric materials. Such testing procedures highlight changes in polymers' physical and mechanical properties, including increased brittleness, elasticity reduction, color alteration, and overall weakening of mechanical properties. Determining polymer performance under UV-C exposure thus ensures product reliability and safety, especially in applications prone to intensive ultraviolet radiation.

Finally, the fifth testing condition utilized was a saline solution formulated in line with ISO 16750-4:2010 Road Vehicles - Climatic Loads [23]. This specific solution had a salinity concentration of 25%, a pH value of 2.162, and a maintained immersion temperature of 0.5 °C. Preparation involved combining 25 liters of demineralized water, 8.34 kilograms of salt, and 30 milliliters of hydrochloric acid, thereby creating a highly controlled testing environment simulating harsh saline exposure. After removal from all these three liquids, the specimens were wiped with a swab to remove excess water from the surface and then weighed again to determine the degree of liquid absorption in each material studied.

After completion of the drying process, each specimen was weighed and then immersed in the selected test medium, namely distilled water, cooling oil, and saline, and exposed to UV-C radiation for a duration of 24 hours. After exposure, the specimens were weighed again to assess the liquid absorbance for distilled water, cooling oil, and saline according to the procedure described by ISO 62:2008. In the final step, after the drying process, the specimens were weighed once more to quantify the amount of liquid absorbed. The following equation (1) was used to calculate the liquid absorption:

$$c = \frac{m_2 - m_1}{m_1} x\ 100\% \qquad (1)$$

The steps followed in preparing the test specimens for testing are shown in Figure 4.

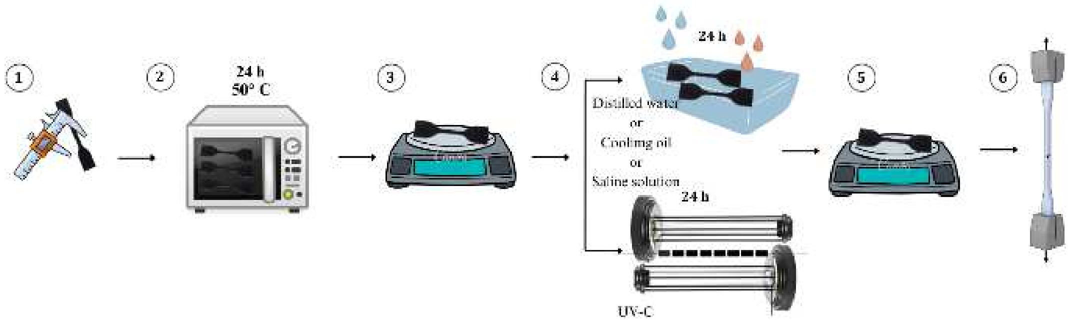

***Fig. 4.*** *Steps to perform the tensile test 1- measuring the specimens, 2 - oven drying, 3 - weighing after drying, 4 - immersion / exposure to the medium of interest, 5 - absorption weighing, 6 - uniaxial tensile test.*

## 3. RESULTS

The results obtained after uniaxial tensile tests performed on the samples maintained in the five environments studied are detailed in the following section. To ensure the accuracy and relevance of the data, ten specimens were used for each medium tested (Figure 5). Data from the five distinct groups, each consisting of ten specimens, were then analyzed and interpreted.

**Fig. 5.** PVC specimens before tensile tests.

Following the tensile tests, the experimental results were subjected to statistical analysis using Minitab 18 software. This analysis focused on two essential aspects: the detection of possible outliers (using the Grubbs test) and the verification of the normality of the data distribution (using the Anderson-Darling test).

The results after testing in all five environments are shown in Tables 1-5, which includes the obtained statistical indicators (AD and G) and the p-values related to the mentioned tests

In many industrial applications, it is very important to know the mechanical and elastic characteristics of the materials used so that the correct choice of material can be made, thus avoiding overstressing that could lead to part failure. The determination of the maximum values for stress and strain allows the proper design of components and the prevention of their premature deterioration under various working conditions [22].

*Table 1*

**Experimental results and statistical analysis for PVC specimens tested in ambient environment.**

| **Specimen No.** | $\sigma_{max}$ | $\varepsilon_{max}$ | **E** |
|---|---|---|---|
| | **[MPa]** | **[%]** | **[MPa]** |
| #1 | 41.71 | 19.39 | 1652.49 |
| #2 | 46.42 | 18.08 | 1730.82 |
| #3 | 44.64 | 18.10 | 1707.66 |
| #4 | 41.50 | 19.20 | 1668.26 |
| #5 | 46.89 | 21.83 | 1676.39 |
| #6 | 46.04 | 19.06 | 1714.76 |
| #7 | 38.19 | 22.60 | 1801.29 |
| #8 | 44.15 | 15.14 | 1815.73 |
| #9 | 43.55 | 18.84 | 1654.26 |
| #10 | 43.92 | 17.06 | 1671.94 |
| *Mean* | 43.70 | 18.93 | 1709.36 |
| *Median* | 44.04 | 18.95 | 1692.03 |
| *Standard deviation* | 2.65 | 2.15 | 58.41 |
| *Minimum* | 38.19 | 15.14 | 1652.49 |
| *Maximum* | 46.89 | 22.60 | 1815.73 |
| *AD Value* | 0.30 | 0.34 | 0.60 |
| *p Value (AD)* | 0.51 | 0.43 | 0.08 |
| *G Value* | 2.08 | 1.75 | 1.82 |
| *p Value (Grubbs)* | 0.17 | 0.58 | 0.46 |

*Table 2*

**Experimental results and statistical analysis for PVC specimens tested after immersing in distilled water.**

| **Specimen No.** | $\sigma_{max}$ | $\varepsilon_{max}$ | **E** |
|---|---|---|---|
| | **[MPa]** | **[%]** | **[MPa]** |
| #1 | 47.92 | 20.90 | 1703.24 |
| #2 | 45.41 | 20.46 | 1694.67 |
| #3 | 43.55 | 18.94 | 1654.26 |
| #4 | 42.55 | 21.48 | 1656.62 |
| #5 | 43.92 | 17.06 | 1671.94 |
| #6 | 37.32 | 19.50 | 1617.02 |
| #7 | 44.18 | 15.83 | 1683.69 |
| #8 | 49.12 | 14.85 | 1679.70 |
| #9 | 50.69 | 17.56 | 1727.09 |
| #10 | 40.43 | 16.04 | 1646.71 |
| *Mean* | 44.51 | 18.26 | 1673.50 |
| *Median* | 44.05 | 18.25 | 1675.82 |
| *Standard deviation* | 4.02 | 2.32 | 31.47 |
| *Minimum* | 37.32 | 14.85 | 1617.02 |
| *Maximum* | 50.69 | 21.48 | 1727.09 |
| *AD Value* | 0.24 | 0.25 | 0.13 |
| *p Value (AD)* | 0.72 | 0.68 | 0.98 |
| *G Value* | 1.77 | 1.47 | 1.79 |
| *p Value (Grubbs)* | 05.6 | 1.00 | 0.51 |

*Table 3*

**Experimental results and statistical analysis for PVC specimens tested after immersing in cooling oil.**

| **Specimen No.** | $\sigma_{max}$ | $\varepsilon_{max}$ | **E** |
|---|---|---|---|
| | **[MPa]** | **[%]** | **[MPa]** |
| #1 | 40.99 | 21.59 | 1649.44 |
| #2 | 43.73 | 21.30 | 1681.25 |
| #3 | 42.21 | 18.94 | 1661.49 |
| #4 | 48.25 | 22.38 | 1722.67 |
| #5 | 46.27 | 18.08 | 1671.95 |
| #6 | 40.31 | 22.51 | 1658.12 |
| #7 | 50.48 | 18.39 | 1728.96 |
| #8 | 42.68 | 20.34 | 1700.08 |

| | | | |
|---|---|---|---|
| #9 | 47.66 | 23.01 | 1566.71 |
| #10 | 51.99 | 18.13 | 1810.05 |
| *Mean* | 45.46 | 20.47 | 1685.07 |
| *Median* | 45.00 | 20.82 | 1676.60 |
| *Standard deviation* | 4.07 | 1.95 | 63.19 |
| *Minimum* | 40.31 | 18.08 | 1566.71 |
| *Maximum* | 51.99 | 23.01 | 1810.05 |
| *AD Value* | 0.27 | 0.47 | 0.34 |
| *p Value (AD)* | 0.61 | 0.20 | 0.41 |
| *G Value* | 1.61 | 1.31 | 1.98 |
| *p Value (Grubbs)* | 0.89 | 1.00 | 0.26 |

*Table 4*

**Experimental results and statistical analysis for PVC specimens tested after UV-C rays exposed.**

| **Specimen No.** | $\sigma_{max}$ | $\varepsilon_{max}$ | **E** |
|---|---|---|---|
| | **[MPa]** | **[%]** | **[MPa]** |
| #1 | 39.06 | 18.85 | 1532.65 |
| #2 | 41.14 | 21.01 | 1558.18 |
| #3 | 41.43 | 20.18 | 1581.89 |
| #4 | 37.59 | 19.29 | 1535.00 |
| #5 | 44.33 | 20.69 | 1573.40 |
| #6 | 41.70 | 19.05 | 1531.27 |
| #7 | 38.82 | 18.74 | 1511.91 |
| #8 | 38.43 | 22.90 | 1503.77 |
| #9 | 40.38 | 17.61 | 1468.21 |
| #10 | 36.34 | 18.49 | 1665.73 |
| *Mean* | 39.92 | 19.68 | 1546.20 |
| *Median* | 39.72 | 19.17 | 1533.82 |
| *Standard deviation* | 2.33 | 1.54 | 53.78 |
| *Minimum* | 36.34 | 17.61 | 1468.21 |
| *Maximum* | 44.33 | 22.90 | 1665.73 |
| *AD Value* | 0.18 | 0.34 | 0.36 |
| *p Value (AD)* | 0.88 | 0.41 | 0.38 |
| *G Value* | 1.89 | 2.10 | 2.22 |
| *p Value (Grubbs)* | 0.36 | 0,15 | 0.08 |

*Table 5*

**Experimental results and statistical analysis for PVC specimens tested after immersing in saline solution.**

| **Specimen No.** | $\sigma_{max}$ | $\varepsilon_{max}$ | **E** |
|---|---|---|---|
| | **[MPa]** | **[%]** | **[MPa]** |
| #1 | 46.81 | 25.53 | 1580.97 |
| #2 | 47.48 | 24.31 | 1568.00 |
| #3 | 37.45 | 28.33 | 1627.83 |
| #4 | 41.59 | 25.71 | 1601.45 |
| #5 | 33.90 | 25.89 | 1556.15 |
| #6 | 32.69 | 26.14 | 1608.01 |
| #7 | 39.74 | 25.75 | 1689.06 |
| #8 | 38.11 | 26.65 | 1661.52 |
| #9 | 36.76 | 26.66 | 1686.87 |
| #10 | 36.43 | 27.98 | 1637.25 |
| *Mean* | 39.10 | 26.29 | 1621.71 |
| *Median* | 37.78 | 26.01 | 1617.92 |
| *Standard deviation* | 4.95 | 1.18 | 47.24 |
| *Minimum* | 32.69 | 24.31 | 1556.15 |
| *Maximum* | 47.48 | 28.33 | 1689.06 |
| *AD Value* | 0.38 | 0.38 | 0.21 |
| *p Value (AD)* | 0.34 | 0.38 | 0.81 |
| *G Value* | 1.69 | 1.72 | 1.43 |
| *p Value (Grubbs)* | 0.70 | 0.64 | 1.00 |

It can be observed that in the case of the AD test, the values of AD and p for $\sigma_{max}$, $\varepsilon_{max}$, and E fall in ranges of values greater than 0.05 and the same is true in the case of the Grubbs test, the values of G and p for $\sigma_{max}$, $\varepsilon_{max}$ and E fall in ranges of values greater than 0.05, all of these confirming that the results obtained are showing a normal distribution of the data, which is also confirmed by the values of p, greater than 0.05.

Based on the experimental results, characteristic curves engineering stress vs. engineering strain were plotted for each of the ten test sets in all five environments. In Figure 6 there are presented, for each environment, a mean curve, made based on all ten curves plotted for all sample tested in each case.

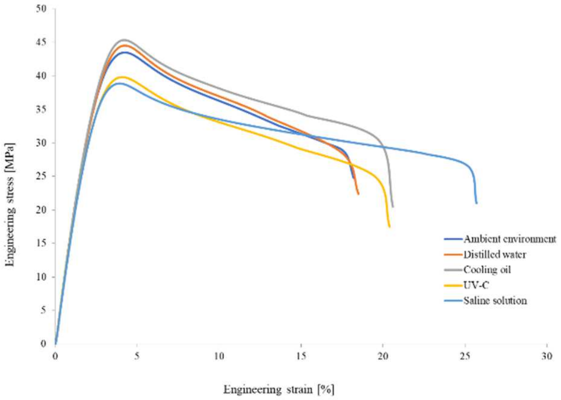

**Fig. 6.** Mean stress-stress for tensile testing of PVC in five studied environments.

Figure 7 shows a graph comparing the mean values of the maximum normal maximum stress obtained for all the five studied environments.

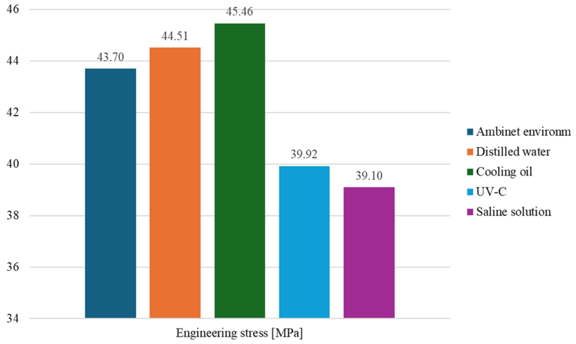

**Fig. 7.** Mean values of the maximum engineering stress for PVC specimens obtained for all five studied environments.

It can be seen from this graph that, taking as a baseline the results obtained when specimens were tested in ambiental environment not previously subjected to any external agresive factor, for all the other four cases of media in which specimens were previously subjected to external factor testing, the maximum stress increases for case of distilled water and cooling oil, while it decreases for case of UV-C radiations and saline solution. Thus, in the case of specimens immersed in distilled water, there is an increase of 1.82% in this maximum stress, in the case of specimens immersed in cooling oil, the increase is 3.86%, in the case of specimens subjected to UV-C radiations, the decrease is 9.47%, and in the case of specimens immersed in saline solution, the decrease is even greater, 11.78%.

It can be concluded, therefore, that all two of the four media exert a negative influence by reducing the normal tension, namely UV-C radiation and saline. In terms of absorbance, it can be noted that the highest absorbance of 0.33% is recorded for specimens immersed in distilled water, followed by specimens immersed in saline solution with an absorbance of 0.29%, and the lowest absorbance of 0.19% is recorded for cooling oil, as shown in Figure 8.

Figure 9 shows a graph comparing the mean values of the maximum engineering strain obtained for all the five environments studied.

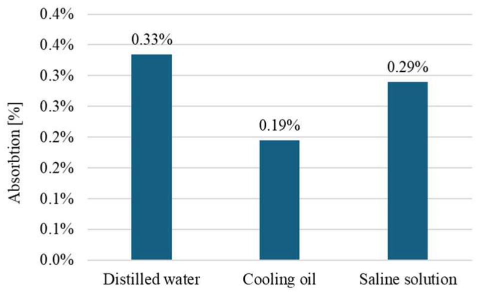

**Fig. 8**. Mean absorption level in PVC specimens for all three liquids studied

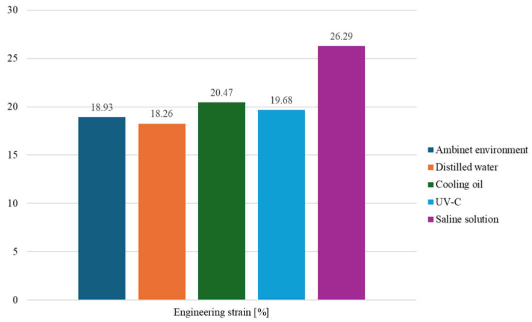

**Fig. 9.** Mean values of the maximum engineering strain for PVC specimens obtained for all five studied environments.

Again, changes in the values of the maximum engineering strain can be observed compared to the values recorded for specimens tested in ambiental environment and not previously subjected to any external factor for all four other cases where the specimens were previously subjected to an external factor (distilled water, cooling oil, UV-C radiation, and saline solution). Thus, in the case of specimens immersed in distilled water, a decrease in the maximum engineering strain of 3.66% is observed, and in the case of specimens subjected to UV-C radiation, an increase (the smallest) of 3.82% is observed. In the case of saline solution, we have a significant increase in the maximum engineering strain of 38.91%, and in the case of cooling oil, we find an increase in the maximum value for the engineering strain of 8.12%.

It can therefore be concluded that distilled water has a negative influence on the maximum engineering strain of PVC specimens, with the maximum elongation being reduced by 3.66% compared to specimens tested in an ambient environment and not previously subjected to any external factor. However, it should also be pointed out that the saline solution increases the maximum engineering strain by more than 38%.

Figure 10 shows a graph that compares the mean values of the maximum tensile modulus (E) obtained for all the five environments studied.

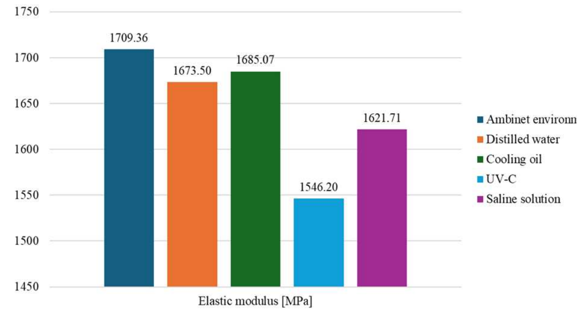

**Fig. 10.** Mean values of tensile modulus for PVC specimens obtained for all five studied environments.

Also, in this case of the tensile modulus, decreases in the values of the maximum engineering strain can be observed compared to the values recorded for specimens tested in an ambient environment and not previously subjected to any external factor, for all the other four cases where the specimens were previously subjected to an external factor (distilled water, cooling oil, UV-C radiation, and saline solution). It can be seen from this graph that, taking as a baseline the results obtained when the specimens were tested in an ambient environment without any external factor, for all the other four cases where the specimens were previously tested with an external factor, the tensile modulus of elasticity shows some changes. Thus, in all four cases there are constant decreases in the tensile modulus. In the case of distilled water, the decrease is 2.14%, in the case of cooling oil there is a decrease (the smallest) of 1.44%, in the case of UV radiation type C, the decrease is 10.55% (the largest), and in the case of saline solution the decrease is only 5.40%.

## 4. DISCUSSION

The results obtained in this study offer a detailed insight into the effects of different industrial environments on the mechanical properties of PVC. Distilled water and cooling oil resulted in a slight increase in tensile strength, while exposure to UV-C radiation and saline caused a significant decrease in mechanical properties.

Distilled water could probably act as a temporary plasticizer, reducing internal stresses in the polymer matrix and improving intermolecular bonds. However, extended exposure could lead to hydrolysis and degradation over time. Cooling oil could provide a more even stress distribution in the PVC matrix, minimizing localized stress points and improving tensile strength. The significant reduction in tensile strength under UV-C radiation is attributed to the degradation of polymer chains under exposure to high ultraviolet energy. This degradation is accentuated by the formation of free radicals, leading to surface embrittlement and microcracking. In the case of salt solution, the decrease in mechanical performance suggests that salt ions penetrate into the polymer structure, weakening intermolecular forces and causing microstructural degradation.

These findings underline the importance of choosing appropriate PVC formulations and applying protective treatments to ensure its durability and reliability in industrial applications.

## 5. CONCLUSIONS

The study of the mechanical behavior of PVC material in different industrial environments showed considerable changes in its elastic and structural properties, determined by the interaction with aggressive external factors. Extended exposure to distilled water and cooling oil led to a moderate increase in the maximum stress supported, suggesting a possible relaxation of the polymer matrix by plasticization effects. In contrast, treatment with UV-C radiation and saline solution enhanced the degradation processes, manifested by a decrease in mechanical strength and a significant reduction in material elasticity.

Liquid adsorption was identified as a determinant of microstructural changes, directly influencing the mechanical stress behavior. Analysis of the results indicated a decrease in the tensile modulus for all samples exposed to external factors, the most significant degradation being observed in the case of UV-C radiation.

The statistical validation of the experimental data confirmed the normal distribution of the results and allowed the detection of possible outliers, reinforcing the robustness of the methodology used. The results obtained indicate the need to implement advanced PVC material selection and treatment strategies to extend the lifetime of components subjected to severe industrial conditions and optimize their performance in critical operational environments.

To improve our understanding of PVC behavior under industrial conditions, future research could explore the effects of long-term exposure to aggressive environments beyond the 24-hour range used in this study. Assessing the impact of extreme temperatures on mechanical performance could provide additional information on material stability. The development of hybrid materials, combining PVC with tougher polymers or nanomaterials, could be a solution to improve mechanical properties. Case studies carried out in real industrial environments over extended periods of operation could provide practical insight into the degradation of PVC and the measures needed to extend its lifetime. This future research will contribute to the optimization of PVC-based materials for improved durability and performance in demanding industrial environments.

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## Impactul agenților industriali asupra materialului PVC

***Rezumat***: *Acest studiu analizează influența factorilor industriali asupra materialului policlorură de vinil, concentrându-se pe modificările mecanice și elastice cauzate de diferite medii de expunere. Policlorură de vinil este utilizat pe scară largă datorită costului scăzut și proprietăților sale chimice versatile, dar expunerea la diverşi factori de mediu poate afecta în mod semnificativ performanța sa. În cadrul cercetării, epruvetele de policlorură de vinil au fost testate la tracțiune uniaxială după imersarea în apă distilată, ulei de răcire, soluție salină și radiații ultraviolet de tip C. Probele au fost imersate timp de 24 de ore, urmate de teste mecanice în conformitate cu ISO 527-2 și ISO 62:2008. Rezultatele au arătat că apa distilată și uleiul de răcire au dus la o creştere a tensiunii maxime, în timp ce radiațiile ultraviolete de tip C și soluția salină au cauzat o reducere semnificativă a rezistenței la tracțiune. Analiza statistică efectuată cu Minitab 18 a confirmat distribuția normală a datelor și a permis identificarea valorilor aberante. Studiul evidențiază necesitatea de a selecta materialele în funcție de condițiile de utilizare, prevenind degradarea prematură a componentelor din policlorură de vinil în medii industriale agresive.*

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