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DURABILITY OF PHYSICAL AND MECHANICAL PROPERTIES OF POLYMERS EXPOSED TO CHEMICAL AND CLIMATIC ENVIRONMENTS

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Abstract. Polymeric materials are widely used in military and defence applications, including personal and vehicle ballistic protection, protective masks and suits, vehicle components, and ammunition transport and storage packaging. In these applications, polymers are exposed to harsh environmental conditions and extreme temperatures, which can significantly affect their long-term performance. In this study, commercially available polymeric materials based on polyethylene (PE), polypropylene (PP) modified with thermoplastic elastomer (TPE) at different PP/TPE compositions, polyetheretherketone (PEEK), and polyamide (PA) were studied. The materials were exposed to selected chemical agents, namely fuels (gasoline) and decontaminants (hypochlorite decontamination mixture), as well as to climatic conditions including high (+100 °C) and low (−40 °C) temperatures, high humidity and UV radiation. The aim of this study was to determine the durability physical and mechanical properties of the polymers in the selected environments with increasing exposure time (from one to six weeks). Hardness (Rockwell and Shore methods), tensile strength, elongation, and tensile modulus were observed. The results showed that exposure to gasoline and UV radiation caused the most pronounced changes. Among the tested materials, PE exhibited the highest overall resistance, showing only minor degradation even under the most aggressive conditions, such as gasoline exposure and UV radiation.

Keywords: Durability, polymers, chemical resistance, climatic resistance, physical and mechanical properties.

1. Introduction

Polymeric materials play a crucial role in national defence, finding extensive use in various military applications, such as personal and vehicle ballistic protection, protective masks and suits, vehicle components, and ammunition transport and storage packaging. In defence applications, polymers must retain their functionality after exposure to extreme environmental conditions, such as high and low temperatures, high humidity, seawater, salt spray, and UV radiation. Additionally, chemical resistance against fuels, decontamination agents, and solvents is required. All these factors have a significant impact on the physical and mechanical properties, durability, and overall performance of the materials [1–3].

Polymers offer numerous advantages, including light weight, low density, high stiffness and strength, corrosion resistance, climatic resistance, economic efficiency, and high durability [4–6]. One of the commonly used polymers for military and defence components is polyethylene (PE) [5, 7]. A major advantage of PE is its excellent chemical resistance to non-oxidising acids, alkalis, and many aqueous solutions. However, exposure to UV light can cause embrittlement of the material. The mechanical properties of PE depend on molar mass and branching degree [8]. PE is classified according to its density. Low density PE (LDPE) is a tough and flexible polymer with long branches, high density PE (HDPE) has more linear chains that can pack more closely, ultra-high molecular weight PE (UHMWPE) is characterised by long and linear chains, and crosslinked PE (PEX) contains crosslinked bonds that enhance its resistance to high temperatures and chemicals [9–11].

Another polymer used in military applications is polypropylene (PP). PP exhibits high strength, toughness, high melting point, and high chemical resistance. Its main advantage is high temperature resistance, however, PP is not suitable for use at temperatures below 0 °C. PP also has good impact resistance and can be combined with thermoplastic elastomers (TPE) to adjust flexibility and elongation properties [12, 13].

Polyetheretherketone (PEEK) is a high-performance polymer with very good chemical resistance, able to resist the corrosion of most chemicals even at high temperatures. The only chemical capable of dissolving PEEK is concentrated sulfuric acid [14, 15]. Additional advantages of PEEK include its resistance to radiation and its high impact strength [15].

Polyamides (PA) represent a class of polymers that have been extensively studied and widely used in numerous applications. PA exhibits excellent mechanical strength, durability, good stability at high temperatures (up to 130 °C), and high chemical resistance, including resistance to fuels and oils. A disadvantage of PA is its hygroscopicity, which can lead to water absorption, affecting the mechanical performance [16, 17].

In this study, commercially available polymeric materials based on polyethylene (PE), polypropylene (PP) modified with thermoplastic elastomer (TPE) at different PP/TPE compositions, polyetheretherketone (PEEK), and polyamide (PA) were exposed to chemical and climatic conditions to evaluate their durability. Chemical resistance was tested with fuels (gasoline) and decontaminants (hypochlorite decontamination mixture), while climatic resistance was evaluated under high (+100 °C) and low (−40 °C) temperatures. The aim of this study was to provide new insights into the durability of military-grade polymers and their suitability for harsh environments focusing on hardness, tensile strength, elongation, and tensile modulus. Unlike previous studies, this work systematically compares the durability of multiple polymers under identical environmental conditions.

2. MATERIALS AND METHODS

2.1. MATERIALS

For this study, commercially available polymeric materials, supplied directly by their manufacturers, were used. Commercial products based on polyethylene (PE, SIMONA® PE-HD black), polypropylene (PP, PP Mosten GB218) with varying thermoplastic elastomer content (TPE, ENFLEX VU-420-80A), polyetheretherketone (PEEK, TECACOMP PEEK TRM XS black), and polyamide 6 (PA, Tecomid® NB40 NL E) were selected. The PP/TPE materials were supplied by the manufacturer in the specified compositions (0, 50, and 100 % of TPE). The test specimens were manufactured by injection moulding in the form of type 1A test specimens according to the ČSN EN ISO 527-2 standard [18].

2.2. ENVIRONMENTAL CONDITIONS

The test specimens were exposed to high (+100 °C) and low (−40 °C) temperatures in the Weiss SB-11-160/80 and ClimeEvent C/340/70/30 climatic chambers. These temperatures were selected to simulate extreme thermal conditions that may occur during military storage and operations. Samples were removed from the chamber after 2, 4, and 8 weeks of exposure.

The test specimens were also placed in a condensation chamber, where they were exposed to continuous condensation at a temperature of 40 ± 3 °C and 100 % relative humidity, according to DIN 50017 [19]. The exposure durations were also 2, 4, and 8 weeks.

The effect of UV radiation was investigated using a Xenotest with a wavelength range of 300 to 400 nm, according to ČSN EN ISO 16474-2 [20]. Exposure durations were also 2, 4 and 6 weeks.

Chemical resistance was assessed by immersing the test specimens in gasoline and hypochlorite decontamination mixture. Exposure durations were 1, 2, and 3 weeks.

2.3. TENSILE TEST

Tensile tests were performed using an INSTRON 5985 universal testing machine according to the ČSN EN ISO 527-1:2020 and ČSN EN ISO 527-2:2012 standards [18, 21]. The tests involved uniaxial tension of type 1A test specimens along their longitudinal axis at a constant crosshead speed of $50\,\mathrm{mm\,min^{-1}}$, applied until fracture. The selected crosshead speed complies with the standard for plastics with moderate to high ductility and was chosen to ensure a reliable comparison of mechanical properties of materials with significantly different elongation behaviour. Tensile strength (σ_t), elongation (ε_t), and tensile modulus (E_t) were calculated from the measured data. For each material, five test specimens were tested under identical conditions and the mean values and standard deviation were calculated in order to provide a statistical evaluation of the mechanical performance. All tests were carried out under controlled laboratory conditions in order to ensure reproducibility and comparability of the results.

2.4. HARDNESS TEST

Hardness measurements were performed according to the standards ČSN EN ISO 2039-2 [22] and ČSN EN ISO 48-4 [23] using Shore D (HSD), Rockwell R (HRR), and Rockwell M (HRM) hardness testing methods. These tests involved measuring the depth of indentations created by a defined intender under a specific load and dwell time. Hardness was selected as a complementary parameter to tensile properties, providing information on surface resistance to deformation and potential wear behaviour under environmental exposure. For each material, hardness was measured on five test specimens under identical conditions. The mean values and standard deviation were calculated in order to provide a statistical evaluation of the mechanical performance. All tests were carried out under controlled laboratory conditions in order to ensure reproducibility and comparability of the results.

3. RESULTS AND DISCUSSION

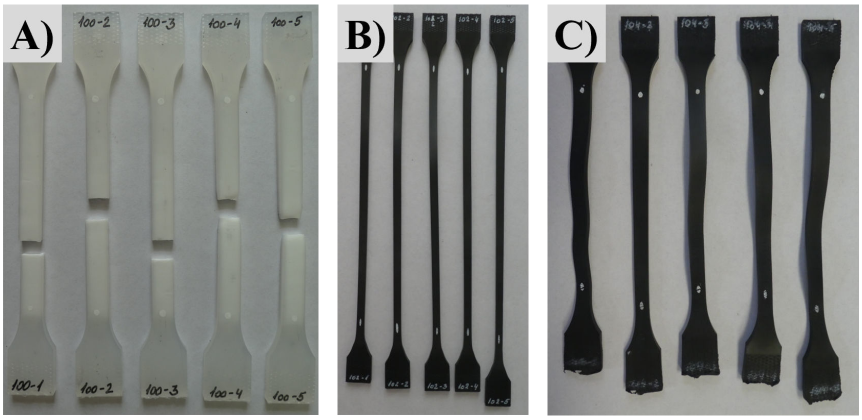
3.1. UNEXPOSED MATERIALS

First, the selected materials were tested before the environmental exposure. The results of the tensile and hardness tests are summarised in Table 1. The highest tensile modulus was observed for PEEK and PA, indicating their high strength and stiffness compared to the other tested polymers. Both materials also exhibited the lowest tensile elongation, which is consistent with their relatively brittle fracture behaviour.

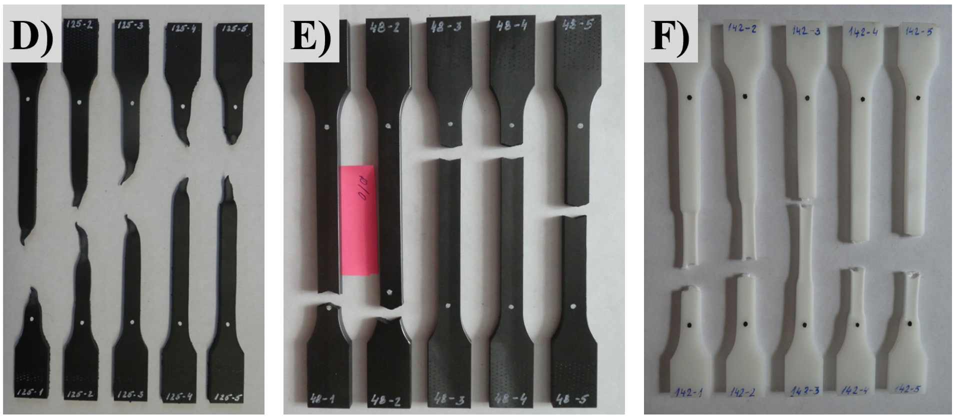
PEEK and PA showed high hardness values, with PEEK exhibiting the highest hardness among all tested materials. When the HRR scale was used to determine the hardness of PEEK, the measured values exceeded the standard measurement range (50–115).

Materials	E_t **[MPa]**	σ_t **[MPa]**	ε_t **[%]**	**HSD [-]**	**HRR [-]**	**HRM [-]**
100PP/0TPE	$1\,640 \pm 30$	35.9 ± 0.1	7.3 ± 0.1	65.8 ± 0.8	88.8 ± 1.8	-
50PP/50TPE	510 ± 20	13.7 ± 0.1	300.0 ± 0.0	59.9 ± 0.6	-	-
0PP/100TPE	90 ± 10	5.6 ± 0.0	292.0 ± 4.5	20.3 ± 0.3	-	-
PE	$1\,370 \pm 20$	28.5 ± 0.3	8.1 ± 0.1	64.4 ± 0.4	61.5 ± 0.9	-
PEEK	$5\,060 \pm 120$	72.7 ± 1.8	3.0 ± 1.0	81.2 ± 0.8	-	85.8 ± 0.5
PA	$2\,960 \pm 60$	73.8 ± 0.4	3.7 ± 0.1	77.0 ± 0.8	114.1 ± 1.1	-

Table 1. Physical and mechanical properties of selected materials: tensile modulus (E_t), tensile strength (σ_t), tensile elongation (ε_t), Shore D hardness (HSD), Rockwell R (HRR), and Rockwell M (HRM) hardness.



(a). 100PP/0TPE. (b). 50PP/50TPE. (c). 0PP/100TPE.



(d). PE. (e). PEEK. (f). PA.

Figure 1. Test specimens after tensile testing.

Therefore, the HRM scale was used according to ČSN EN ISO 2039-2 [22].

The PP/TPE materials were evaluated using three commercially supplied compositions with defined TPE contents (0, 50, and 100 %). As the TPE content increased, the tensile strength and modulus decreased, while elongation increased, demonstrating the expected transition from a rigid to elastomer-dominated mechanical behaviour. The test specimens after tensile testing are shown in Figure 1. Due to the high elongation of materials containing 50 % and 100 % TPE (Figures 1b and 1c), the test specimens did not rupture during tensile testing. In contrast, PE and PA polymers (Figures 1d and 1f) exhibited visible necking.

3.2. Durability of materials in chemical environments

The effect of different chemical environments on the mechanical properties of the tested materials was evaluated following their exposure to either gasoline or a hypochlorite decontamination mixture. Samples were exposed to these chemicals for 1, 2, and 3 weeks. The resulting values of tensile modulus and tensile strength after exposure to gasoilne and hypochlorite decontamination mixture are shown in Figures 2 and 3. The elongation and Shore D hardness values are summarised in Table 2.

Compared to other measured physical-mechanical properties, the hardness of the tested materials was less affected by chemical exposure. Changes in hard-

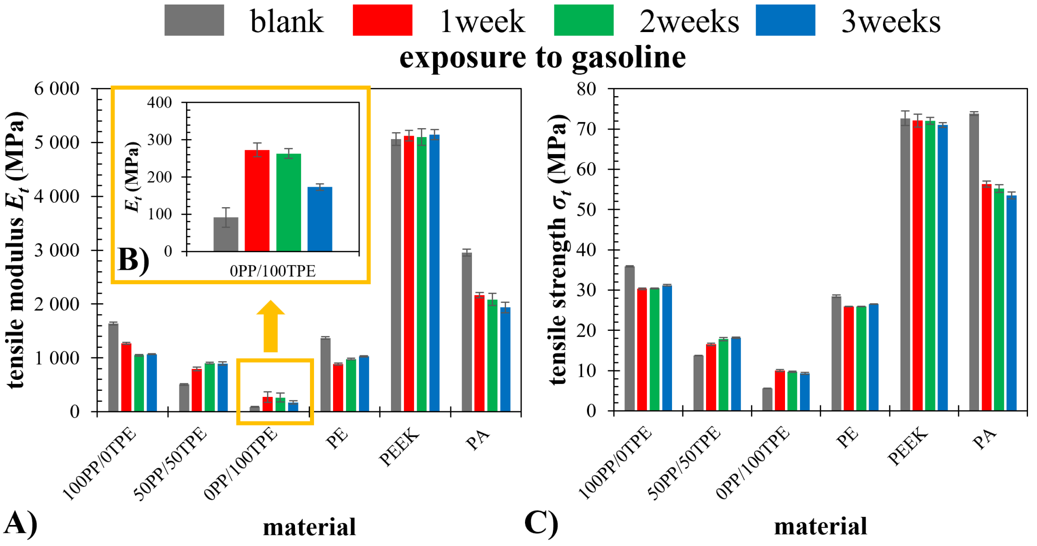


Figure 2. Bar charts showing the measured parameters after 1, 2, and 3 weeks of gasoline exposure, compared to the blank (unexposed material). Chart for A) tensile modulus for all selected; B) tensile modulus for 0PP/100TPE material only (shown separately in order to better visualise changes); C) tensile strength. The results indicate that PEEK and PE were the least affected by the exposure to gasoline.

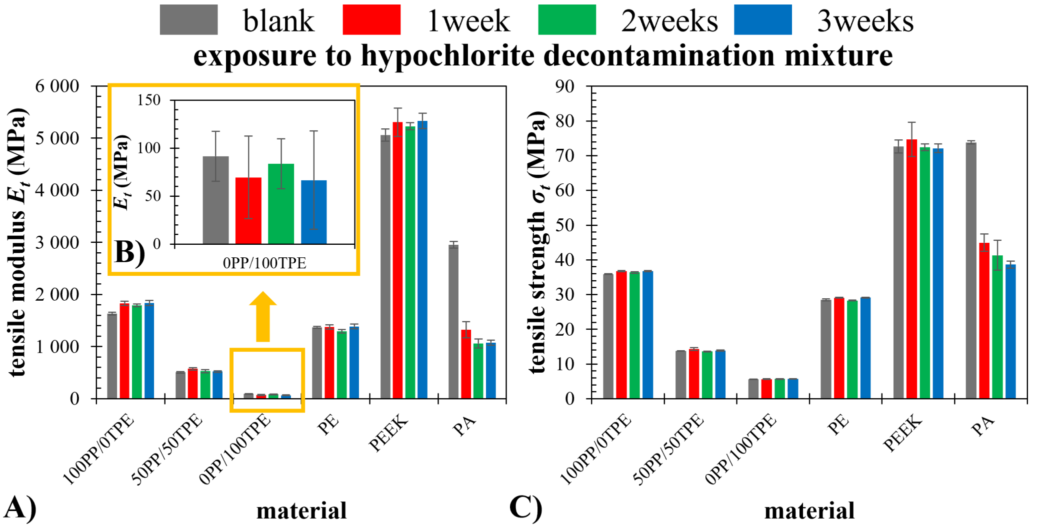


Figure 3. Bar charts showing the measured parameters after 1, 2, and 3 weeks of hypochlorite decontamination mixture exposure, compared to the blank (unexposed material). Chart for A) tensile modulus for all materials; B) tensile modulus for 0PP/100TPE material only (shown separately in order to better visualise changes); C) tensile strength. The results indicate that only PA was strongly affected by the exposure to hypochlorite decontamination.

ness generally did not exceed 20 % relative to the blank samples (unexposed materials). A notable exception was material 0PP/100TPE, where gasoline exposure resulted in a significant hardness increase of up to 80 % compared to the blank sample.

Gasoline had a considerably stronger impact on other measured parameters than the hypochlorite decontamination mixture. For 0PP/100TPE material, the gasoline exposure led to a pronounced increase in tensile modulus and strength; the tensile modulus (E_t) was up to three times higher than that of the blank and the tensile strength (σ_t) increased by nearly 80 %. However, the elongation (ε_t) of the materials was not affected. This behaviour suggests solvent-induced structural changes within the elastomeric material.

The 50PP/50TPE material exhibited a similar trend, although the magnitude of changes was lower. In contrast, gasoline exposure caused a decrease in stiffness and strength of the 100PP/0TPE material, accompanied by a substantial increase in elongation.

The PA polymer was significantly affected by both the gasoline and hypochlorite decontamination mixture, resulting in a decrease in E_t and σ_t. Elongation of PA increased dramatically, reaching a value nearly seven times higher than the blank value.

Of the selected materials, PE and PEEK exhibited the highest chemical resistance, with only minimal changes observed following the exposure to gasoline and a decontamination mixture.

			100PP/0TPE	50PP/50TPE	0PP/100TPE	PE	PEEK	PA
Gasoline	ε_t [%]	Blank	7.3 ± 0.1	300.0 ± 0.0	292.0 ± 4.5	8.1 ± 0.1	3.0 ± 1.0	3.7 ± 0.1
		1wk	14.4 ± 2.1	12.0 ± 0.0	300.0 ± 0.0	12.0 ± 0.0	3.0 ± 0.4	19.2 ± 0.5
		2wk	12.0 ± 0.0	9.1 ± 0.1	302.0 ± 4.5	10.8 ± 1.8	3.0 ± 0.3	19.8 ± 0.5
		3wk	11.0 ± 0.0	9.4 ± 0.5	300.0 ± 0.0	10.0 ± 0.0	2.7 ± 0.2	20.8 ± 0.8
	HSD [-]	Blank	65.8 ± 0.8	59.9 ± 0.6	20.3 ± 0.3	64.4 ± 0.4	81.2 ± 0.8	77.0 ± 0.8
		1wk	61.9 ± 1.6	58.3 ± 0.9	36.0 ± 1.2	62.1 ± 0.2	81.8 ± 0.8	66.8 ± 1.3
		2wk	64.0 ± 0.9	61.4 ± 1.0	33.3 ± 1.5	62.9 ± 0.6	81.7 ± 0.5	64.0 ± 3.7
		3wk	65.4 ± 0.6	65.1 ± 0.4	31.2 ± 1.0	64.4 ± 0.4	81.4 ± 0.6	72.1 ± 0.7
Hypochlorite	ε_t [%]	Blank	7.3 ± 0.1	300.0 ± 0.0	292.0 ± 4.5	8.1 ± 0.1	3.0 ± 1.0	3.7 ± 0.1
		1wk	6.9 ± 0.1	300.0 ± 0.0	290 ± 0.0	8.7 ± 1.3	2.9 ± 0.4	24.4 ± 1.7
		2wk	6.8 ± 0.1	300.0 ± 0.0	290 ± 0.0	8.1 ± 0.1	3.1 ± 0.4	26.5 ± 1.9
		3wk	6.8 ± 0.1	300.0 ± 0.0	290 ± 0.0	8.2 ± 0.1	3.2 ± 0.3	24.2 ± 0.8
	HSD [-]	Blank	65.8 ± 0.8	59.9 ± 0.6	20.3 ± 0.3	64.4 ± 0.4	81.2 ± 0.8	77.0 ± 0.8
		1wk	68.0 ± 2.4	61.9 ± 1.3	20.7 ± 0.3	65.0 ± 0.6	83.5 ± 1.0	68.4 ± 1.6
		2wk	69.2 ± 1.0	62.7 ± 1.0	20.8 ± 0.4	66.1 ± 0.2	80.2 ± 0.4	64.0 ± 4.3
		3wk	71.8 ± 0.8	65.5 ± 0.5	20.8 ± 0.8	66.8 ± 0.4	81.3 ± 0.6	68.4 ± 0.5

Table 2. The resulting values for elongation (ε_t) and Shore D hardness (HSD) for the materials exposed to gasoline and hypochlorite decontamination mixture for 1, 2, and 3 weeks, compared to the blank (values for materials without chemical exposure).

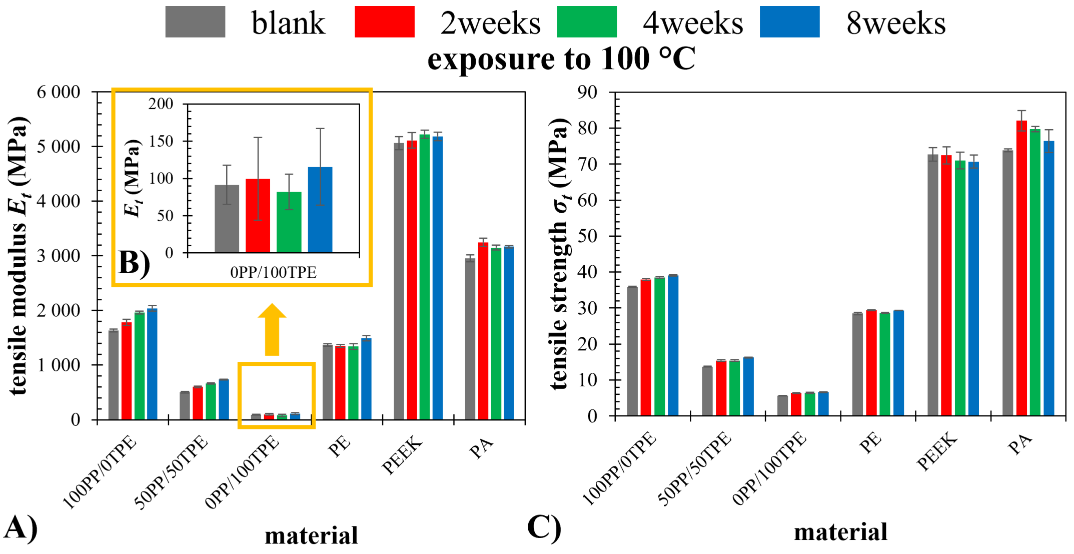


Figure 4. Bar charts showing the measured parameters after 2, 4, and 8 weeks of high temperature (100 °C) exposure, compared to the blank (unexposed material). Chart for A) tensile modulus for all materials; B) tensile modulus for 0PP/100TPE material only (shown separately in order to better visualise changes); C) tensile strength. High temperature exposure had no significant effect on the observed parameters.

3.3. Durability of materials under climatic conditions

In addition to their chemical resistance, the stability of selected materials under climatic conditions was evaluated. The materials were exposed to high (+100 °C) and low (−40 °C) temperatures, high humidity for 2, 4, and 8 weeks, and UV radiation for 2, 4, and 6 weeks. These conditions were chosen in order to simulate the extreme environments that could be encountered in military and defence applications.

The resulting values of tensile modulus and tensile strength after the exposure to high and low temperatures are shown in Figures 4 and 5. The elongation and Shore D hardness values are summarised in Table 3.

The resulting values for tensile modulus and tensile strength after exposure to humidity and UV radiation are shown in Figures 6 and 7. The corresponding elongation and Shore D hardness values are summarised in Table 4.

The measured hardness values indicate that none of the selected climatic conditions caused a substantial change in Shore D hardness, as the observed variations did not exceed 25 %.

The exposure to high and low temperatures did not result in significant changes in tensile properties for most of the investigated polymers, as shown in Figures 4 and 5. For PP-based materials, the temperature response depended on the TPE content. The

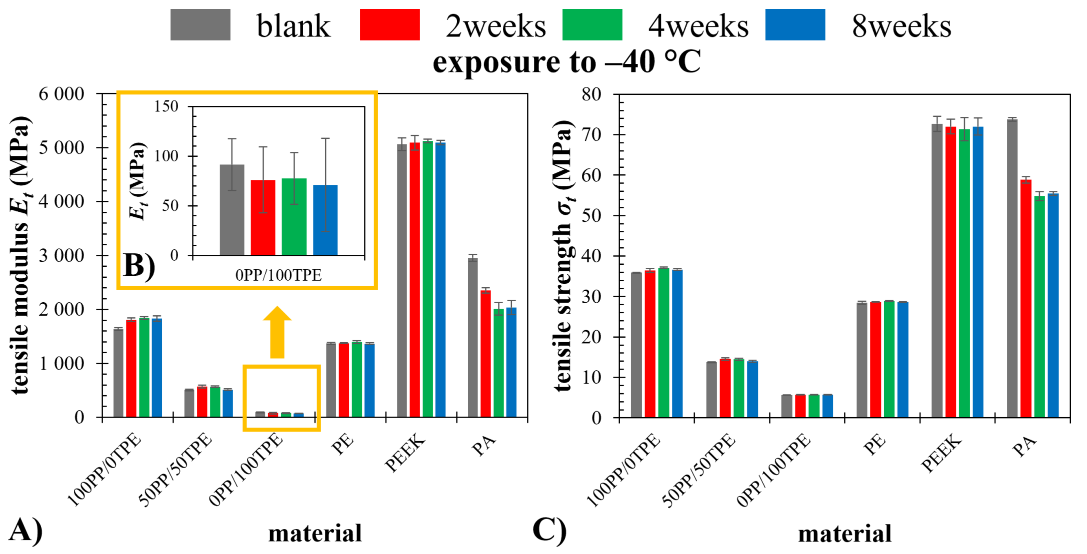


Figure 5. Bar charts showing the measured parameters after 2, 4 and 8 weeks of low temperature (−40 °C) exposure, compared to the blank (unexposed material). Chart for A) tensile modulus for all materials; B) tensile modulus for 0PP/100TPE material only (shown separately in order to better visualise changes); C) tensile strength. Low temperature exposure had no significant effect on the observed parameters.

			100PP/0TPE	50PP/50TPE	0PP/100TPE	PE	PEEK	PA
100 °C	ε_t [%]	Blank	7.3 ± 0.1	300.0 ± 0.0	292.0 ± 4.5	8.1 ± 0.1	3.0 ± 1.0	3.7 ± 0.1
		2wk	6.6 ± 0.1	277.5 ± 28.7	290.0 ± 0.0	8.9 ± 0.1	2.9 ± 0.5	4.1 ± 0.1
		4wk	6.0 ± 0.0	37.2 ± 1.6	260.0 ± 56.6	8.8 ± 0.1	2.7 ± 0.4	16.0 ± 0.0
		8wk	5.7 ± 0.1	150.0 ± 10.0	290.0 ± 0.0	8.6 ± 0.1	2.6 ± 0.4	3.6 ± 0.7
	HSD [-]	Blank	65.8 ± 0.8	59.9 ± 0.6	20.3 ± 0.3	64.4 ± 0.4	81.2 ± 0.8	77.0 ± 0.8
		2wk	69.0 ± 0.9	60.8 ± 0.4	21.8 ± 0.4	65.5 ± 0.5	80.4 ± 0.5	77.9 ± 1.7
		4wk	68.2 ± 0.9	64.3 ± 0.7	21.9 ± 0.7	66.3 ± 0.3	82.9 ± 0.4	79.1 ± 0.2
		8wk	73.1 ± 0.4	66.6 ± 0.4	23.2 ± 0.3	66.6 ± 0.5	79.7 ± 0.4	76.2 ± 0.3
−40 °C	ε_t [%]	Blank	7.3 ± 0.1	300.0 ± 0.0	292.0 ± 4.5	8.1 ± 0.1	3.0 ± 1.0	3.7 ± 0.1
		2wk	6.8 ± 0.0	300.0 ± 0.0	290.0 ± 0.0	8.1 ± 0.0	3.0 ± 0.5	14.8 ± 6.0
		4wk	6.7 ± 0.1	300.0 ± 0.0	294.0 ± 5.5	8.2 ± 0.1	2.9 ± 0.5	19.2 ± 0.4
		8wk	6.7 ± 0.1	300.0 ± 0.0	290.0 ± 0.0	8.1 ± 0.1	3.1 ± 0.4	18.2 ± 1.6
	HSD [-]	Blank	65.8 ± 0.8	59.9 ± 0.6	20.3 ± 0.3	64.4 ± 0.4	81.2 ± 0.8	77.0 ± 0.8
		2wk	65.8 ± 0.3	61.9 ± 0.4	20.8 ± 0.3	64.7 ± 0.3	80.5 ± 0.7	71.6 ± 0.4
		4wk	71.8 ± 0.6	64.1 ± 0.7	21.0 ± 0.0	64.9 ± 0.2	80.1 ± 0.2	77.1 ± 0.5
		8wk	71.2 ± 0.8	63.7 ± 1.0	21.1 ± 0.2	65.4 ± 0.4	80.0 ± 1.0	68.5 ± 2.0

Table 3. The resulting values for elongation (ε_t) and Shore D hardness (HSD) for the materials exposed to high (100 °C) and low (−40 °C) temperatures for 2, 4, and 8 weeks, compared to the blank (values for materials without thermal exposure).

0PP/100TPE material remained largely unaffected at both temperatures, preserving high elongation and elastomeric behaviour. The tensile modulus of the 100PP/0TPE and 50PP/50TPE materials increased with exposure time. After 4 weeks of exposure, elongation decreased rapidly, reaching values approximately two times lower than the blank value.

For PA, the measured tensile parameters did not show significant changes after high and low temperatures exposure. However, despite the apparent stability of tensile modulus and strength, brittle fracture of the test specimens was observed during tensile testing (Figure 8a), indicating a temperature-induced change in the failure mechanism [2]. Additionally, the exposure to 100 °C caused a visible colour change of the surface of the test specimens, from white to yellow (Figure 8b), indicating thermal degradation. This behaviour of PA is consistent with literature reports showing that PA is susceptible to thermal degradation under elevated temperatures, where chain scission and reduction in molecular weight can alter fracture behaviour even if standard tensile parameters remain relatively unchanged [24, 25].

Of the investigated materials, PEEK and PE exhibited the highest thermal stability, with negligible changes in all monitored physical and mechanical parameters at both temperatures, indicating good resistance to thermal ageing.

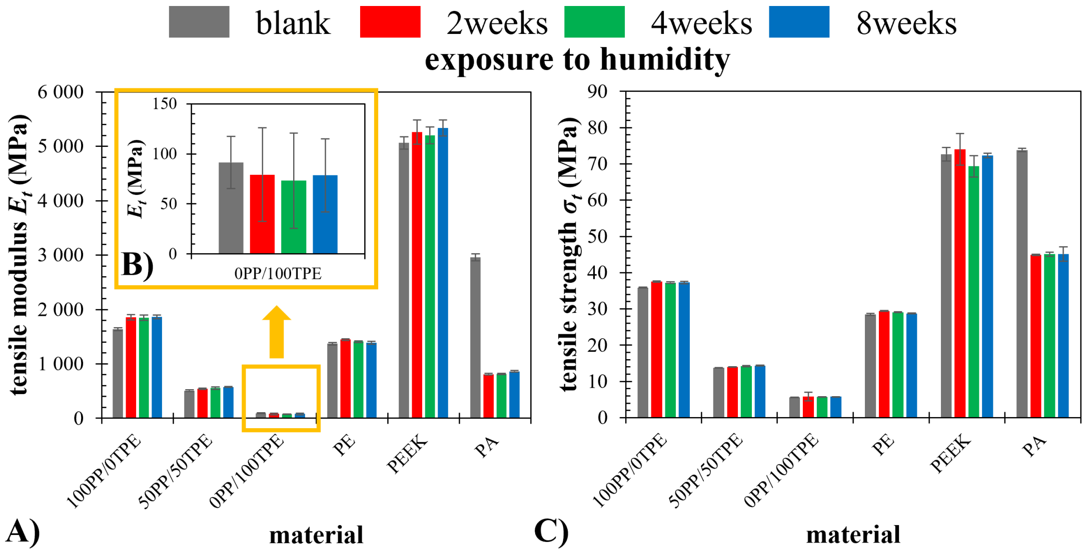


Figure 6. Bar charts showing the measured parameters after 2, 4, and 8 weeks of humidity exposure, compared to the blank (unexposed material). Chart for A) tensile modulus for all materials; B) tensile modulus for 0PP/100TPE material only (shown separately in order to better visualise changes); C) tensile strength. The results indicate that only the PA material was strongly affected by humidity exposure.

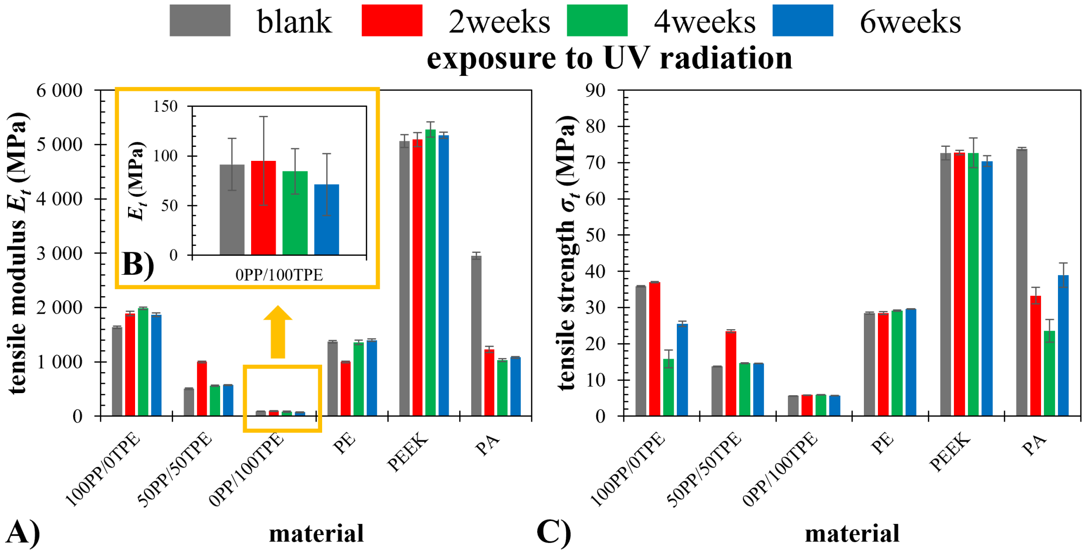


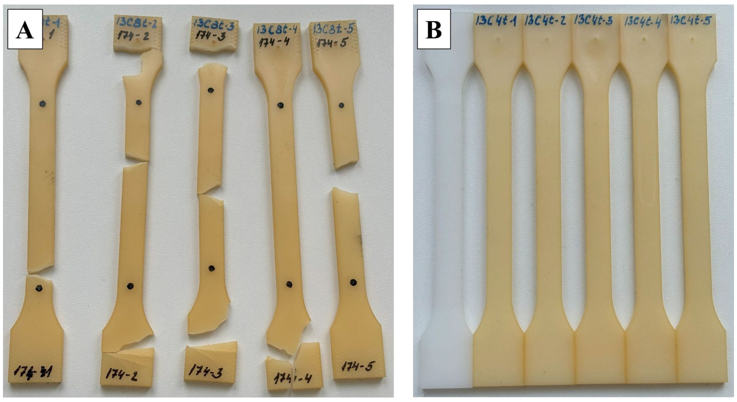
Figure 7. Bar charts showing the measured parameters after 2, 4, and 6 weeks of UV radiation exposure, compared to the blank (unexposed material). Chart for A) tensile modulus for all materials; B) tensile modulus for 0PP/100TPE material only (shown separately in order to better visualise changes); C) tensile strength. The results indicate that 0PP/10TPE, PEEK, and PE were the least affected by UV radiation.

Humidity exposure significantly affected only the PA material. A pronounced decrease in stiffness was observed after 2 weeks of exposure, accompanied by a reduction in tensile strength. Simultaneously, elongation increased markedly, and no specimen failure was observed during the tensile test (Figure 9). This behaviour is associated with the hygroscopic nature of PA, where absorbed water increases molecular mobility and acts as a plasticiser, thereby reducing intermolecular the interactions between polymer chains. These mechanisms are consistent with the known hydromechanical behaviour of PA, where water molecules bound between polymer chain segments increase chain mobility, leading to moisture-induced swelling and mechanical softening [5, 26, 27].

Exposure to UV radiation affected the measured properties of the tested polymers to different extents depending on the material type. UV radiation primarily drives photooxidative degradation, which can break polymer chains through oxidation mechanisms that lead to molecular weight reduction and deterioration of mechanical properties. The most pronounced changes were observed for PA, for which a gradual decrease in tensile modulus and strength was observed. Simultaneously, elongation increased markedly with increasing time exposure, indicating progressive material degradation. This is consistent

			100PP/0TPE	**50PP/50TPE**	**0PP/100TPE**	**PE**	**PEEK**	**PA**
Humidity	ε_t [%]	Blank	7.3 ± 0.1	300.0 ± 0.0	292.0 ± 4.5	8.1 ± 0.1	3.0 ± 1.0	3.7 ± 0.1
		2wk	6.6 ± 0.1	300.0 ± 0.0	290.0 ± 0.5	8.1 ± 0.0	2.8 ± 0.4	300.0 ± 0.0
		4wk	6.4 ± 0.0	300.0 ± 0.0	292.0 ± 4.5	8.1 ± 0.0	2.7 ± 0.7	300.0 ± 0.0
		8wk	6.3 ± 0.1	20.8 ± 0.8	290.0 ± 0.0	8.1 ± 0.1	3.3 ± 0.1	284.0 ± 23.0
	HSD [-]	Blank	65.8 ± 0.8	59.9 ± 0.6	20.3 ± 0.3	64.4 ± 0.4	81.2 ± 0.8	77.0 ± 0.8
		2wk	70.0 ± 0.8	62.6 ± 0.9	19.2 ± 1.0	64.4 ± 0.5	82.0 ± 1.2	57.2 ± 0.8
		4wk	70.4 ± 0.4	62.2 ± 1.4	20.6 ± 0.4	65.1 ± 0.2	82.5 ± 0.5	62.7 ± 0.3
		8wk	71.1 ± 0.7	61.6 ± 1.3	21.0 ± 0.0	66.2 ± 0.4	80.0 ± 0.0	64.5 ± 0.9
UV radiation	ε_t [%]	Blank	7.3 ± 0.1	300.0 ± 0.0	292.0 ± 4.5	8.1 ± 0.1	3.0 ± 1.0	3.7 ± 0.1
		2wk	6.0 ± 0.5	11.8 ± 0.4	290.0 ± 0.0	11.8 ± 0.4	3.2 ± 0.1	6.5 ± 1.1
		4wk	0.9 ± 0.2	300.0 ± 0.0	290.0 ± 0.0	8.4 ± 0.1	2.9 ± 0.5	3.8 ± 1.7
		6wk	2.5 ± 0.2	300.0 ± 0.0	290.0 ± 0.0	8.3 ± 0.1	2.6 ± 0.4	19.8 ± 6.5
	HSD [-]	Blank	65.8 ± 0.8	59.9 ± 0.6	20.3 ± 0.3	64.4 ± 0.4	81.2 ± 0.8	77.0 ± 0.8
		2wk	71.4 ± 0.5	63.2 ± 0.8	21.2 ± 0.3	63.9 ± 0.4	83.1 ± 0.7	71.9 ± 0.5
		4wk	73.4 ± 1.1	65.2 ± 0.8	21.3 ± 0.4	65.8 ± 0.4	80.2 ± 0.3	63.6 ± 1.1
		6wk	69.5 ± 1.0	62.1 ± 0.7	21.5 ± 0.0	66.0 ± 0.4	81.2 ± 0.3	70.1 ± 0.7

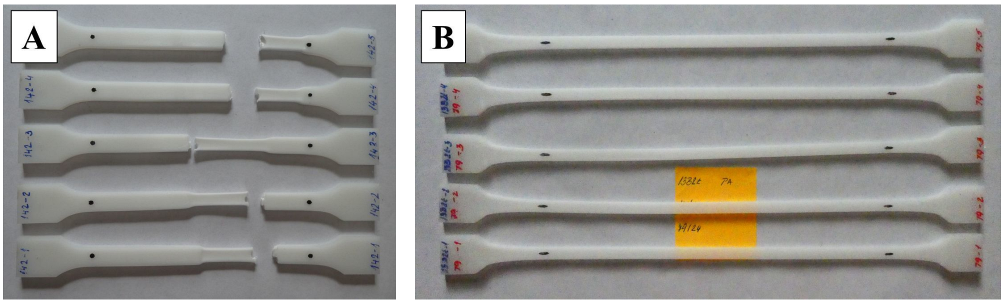
TABLE 4. Resulting values for elongation (ε_t) and Shore D hardness (HSD) for the materials exposed to humidity for 2, 4, and 8 weeks and to UV radiation for 2, 4, and 6 weeks, compared to the blank (values for materials without environmental exposure).



(A). Brittle fraction during tensile test.

(B). Yellowing of the material surface.

FIGURE 8. Effect of high temperature (100 °C) on the PA material.



(A). Without environmental exposure.

(B). After 2 weeks of humidity exposure.

FIGURE 9. PA test specimens.

with known photooxidative behaviour in which UV exposure generates free radicals and oxygen uptake, resulting in chain scission and embrittlement over time [2, 11, 28]. UV radiation caused a reduction in tensile strength and a noticeable decrease in ductility of the 100PP/0TPE material, particularly after 4 weeks of exposure. With increasing TPE content, the effect of UV radiation became progressively less pronounced. In contrast, PEEK and PE exhibited a high resistance to UV radiation, with only minimal changes in mechanical properties over the exposure period, as these materials are generally more stable under photooxidative conditions compared to PA and PP variants [29].

4. Conclusion

Polyethylene (PE), polyetheretherketone (PEEK), polyamide (PA), and polypropylene (PP) with varying thermoplastic elastomer (TPE) content were investigated to evaluate their chemical and climatic resistance. The materials were exposed to gasoline, hypochlorite decontamination mixture, high (100 °C) and low (−40 °C) temperatures, humidity, and UV radiation, representing extreme conditions relevant to military applications. The aim of this work was to assess the stability of the physical and mechanical properties of the selected polymers, namely hardness, tensile strength, elongation, and tensile modulus, under increasing exposure times. The results demonstrated that the investigated polymers exhibited markedly different responses depending on both the material type and the applied environmental factor.

Of all the materials tested, PA showed the lowest resistance to both chemical and climatic exposure. Significant reductions in tensile modulus and tensile strength were observed even after the shortest exposure time, while elongation was particularly affected by humidity, leading to a substantial increase in ductility. Exposure to high temperatures caused a pronounced colour change in the white PA test specimens, which turned yellow after only 2 weeks, indicating thermal degradation. Although there was not significant change in the measured tensile parameters, brittle fractures were observed in the test specimens were observed during tensile testing.

In contrast, PEEK and PE exhibited the highest overall resistance to the investigated conditions. However, the results for PEEK were relatively inconsistent and several measured values had to be excluded as outliers when calculating average values. This variability may be attributed to material inhomogeneity, which was also visually apparent, as individual specimens displayed noticeable colour differences. Based on the overall stability of physical and mechanical properties and consistent performance across all exposure conditions, PE was identified as the material with the highest durability. Consequently, PE represents a promising candidate for applications in defence systems where long-term exposure to harsh chemical and climatic conditions is expected.

List of symbols

E_t	Tensile modulus
ε_t	Elongation
σ_t	Tensile strength
HDPE	High density polyethylene
HRM	Rockwell M hardness
HRR	Rockwell R hardness
HSD	Shore D hardness
LDPE	Low density polyethylene
PE	Polyethylene
PEEK	Polyetheretherketone
PEX	Crosslinked polyethylene
PP	Polypropylene
TPE	Thermoplastic elastomer
UHMWPE	Ultra-high molecular weight polyethylene
UV	Ultraviolet

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