

Experimental Study on Swelling Behavior of PVC Hoses in Various Chemical Environments

Yousif.A A¹, Mohamad H. H. Deifalla²

¹Department of Polymer Engineering, Sudan University of Science and Technology, Khartoum Sudan

²Department Chemical Engineering, Sudan University of Science and Technology, Khartoum Sudan

Email: abdalbagyousif@gmail.com

Abstract— Poly(vinyl chloride) (PVC) hoses are widely used in industrial, agricultural, and domestic applications due to their flexibility, chemical resistance, and low cost. However, exposure to different chemical media, including water, oils, fuels, and alkaline solutions, can induce swelling, affecting mechanical performance and dimensional stability. This study investigates the swelling behavior of commercial PVC hoses under four different media over time. Swelling ratios were measured by monitoring weight and volume changes, and tensile strength tests were conducted to assess mechanical degradation. The results indicate significant dependence of swelling on the chemical environment, with oils and fuels producing the highest swelling ratios and reduction in tensile strength. The study provides guidelines for the selection and design of PVC hoses for chemically aggressive applications.

Keywords— Poly(vinyl chloride) (PVC) hoses; swelling behavior; chemical resistance; mechanical properties; tensile strength; oils; fuels; alkaline solutions; dimensional stability.

I. INTRODUCTION

Polyvinyl chloride (PVC) hoses are essential components in fluid handling systems across various industrial sectors, including potable water transport, chemical distribution, and fuel delivery. While PVC is generally resistant to many chemicals, long-term exposure to aggressive media—such as organic solvents, fuels, oils, and alkaline solutions—can trigger polymer swelling. This swelling compromises dimensional stability, plasticizer retention, and mechanical performance.

Kumar et al. (2020) studied solvent-induced swelling and plasticizer migration in PVC obtained from cable waste, revealing its vulnerability to organic solvents (1). Porpora et al. (2023) introduced a theoretical model linking solvent diffusion and polymer swelling behavior, which is particularly useful for interpreting non-Fickian diffusion phenomena in PVC hoses (2). Wang et al. (2023) further examined molecular diffusion dynamics in polymers, showing how microscopic solvent transport mechanisms dictate large-scale swelling kinetics (3).

Shevchenko et al. (2024) investigated swelling kinetics in polymer materials exposed to blended diesel fuels, offering a quantitative analysis of fuel absorption and polymer expansion (4). Jing et al. (2024) systematically assessed oil resistance and swelling in elastomers using Hansen Solubility Parameters, establishing a predictive correlation applicable to PVC hose design (5). Ling et al. (2023) studied hydrothermal degradation of PVC, demonstrating that combined thermal and chemical exposure significantly accelerates swelling and mechanical failure (6).

Jha et al. (2024) explored PVC's chemical reactivity under solvent influence, attributing swelling to plasticizer migration and polymer matrix relaxation (7). Chen et al. (2022) analyzed how different plasticizers affect PVC swelling and strength, highlighting the importance of

formulation in solvent resistance (8). Zhang et al. (2021) examined PVC tubing under aqueous and alkaline conditions, reporting moderate swelling and tensile degradation in alkaline environments (9).

Santos et al. (2023) evaluated fuel-induced swelling in polymer hoses, recommending material modifications for fuel-related applications (10). Kim et al. (2020) studied mechanical degradation of PVC exposed to oils and solvents, emphasizing the need for barrier layers or improved additives (11). Finally, Li et al. (2024) modeled diffusion kinetics and plasticizer migration under chemical attack, linking molecular diffusion to observed mechanical degradation in PVC structures (12).

Despite these efforts, few experimental studies have addressed the combined chemical and mechanical behavior of commercial PVC hoses in diverse chemical environments. This study addresses that gap by evaluating swelling ratios and tensile strength degradation in PVC hoses immersed in water, alkaline solution, mineral oil, and diesel fuel for extended periods. The swelling behavior of PVC hoses in water, alkaline, oil, and fuel media, and to assess their mechanical performance after exposure.

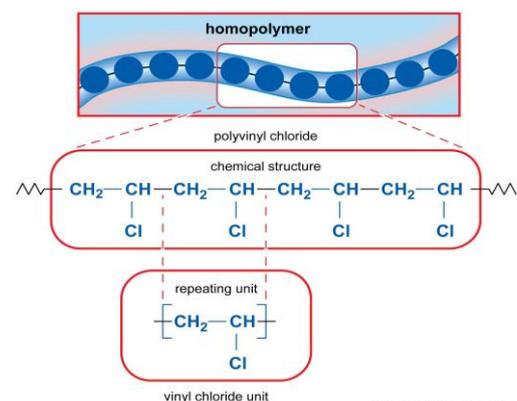


Figure 1: PVC Structure

II. MATERIALS AND METHODS

1. Materials Other Recommendations

The swelling behavior and mechanical performance of PVC hoses were experimentally evaluated after immersion in various chemical environments. Samples were submerged in distilled water, 5% sodium hydroxide (NaOH) solution, mineral oil, and diesel fuel for time intervals of 24, 48, 72, and 168 hours. After each exposure period, swelling ratios were calculated based on weight changes, and tensile strength measurements were performed after 168 hours to assess mechanical degradation. The results are summarized in the following tables. Table 1 presents the swelling ratios over time for each chemical medium, indicating the degree of solvent absorption. Table 2 reports the change in tensile strength before and after chemical exposure, illustrating the extent of mechanical softening or degradation.

- Commercial PVC hoses, inner diameter: 10 mm, wall thickness: 2 mm.
- Test chemicals: distilled water, 5% NaOH solution, mineral oil, diesel fuel.

2. Sample Preparation

Hoses cut into 50 mm lengths. Initial weight (W₀) and length/diameter measured

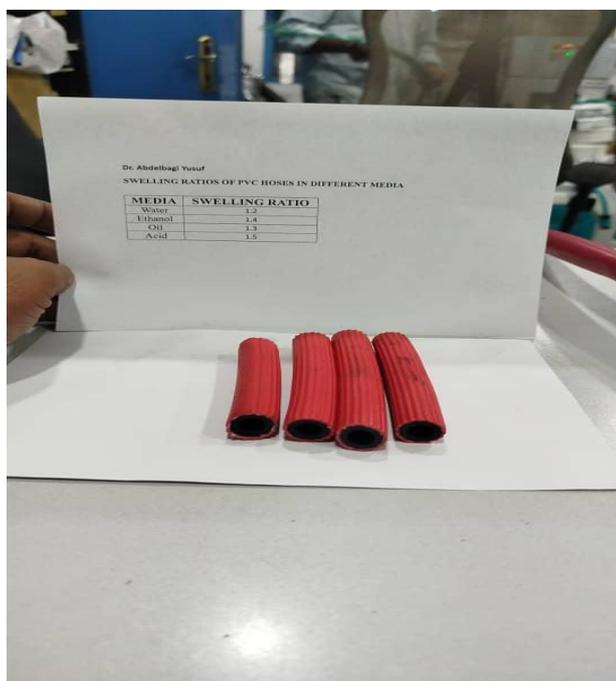


Figure 2: Hoses Samples

3. Swelling Test

- Samples submerged in each chemical medium for 24 h, 48 h, 72 h, and 168 h.



Figure 3: Chemical Materials

After each period, samples removed, surface blotted, and weight (W_t) and dimensions recorded. Swelling ratio calculated as:

$$SW = \frac{W - W_0}{W_0}$$

III. MECHANICAL TESTING

- Tensile strength measured for samples before and after swelling using a universal testing machine (ASTM D412).



Figure 4: Tensile Testing Machine

IV. RESULTS

a. Swelling Ratios

1) Swelling Ratios

TABLE 1: Swelling ratios (%) of PVC hoses after exposure to different chemical media over time

Medium	24 h	48 h	72 h	168 h
Water	1.2%	1.5%	1.7%	2.0%
5% NaOH	1.5%	1.9%	2.3%	2.6%
Mineral Oil	3.5%	4.8%	5.6%	6.5%
Diesel Fuel	4.0%	5.2%	6.0%	7.2%

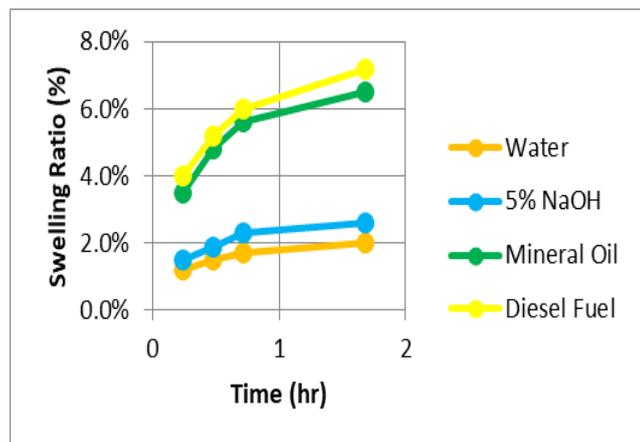


Figure 4: Swelling ratio (%) vs. time for PVC hoses in different chemical media

2) Tensile Strength

TABLE 2: Change in tensile strength of PVC hoses after 168-hour exposure to various chemical media

Medium	Initial (MPa)	After 168 h (MPa)	Reduction (%)
Water	22.5	21.8	3.1%
5% NaOH	22.5	20.9	7.1%
Mineral Oil	22.5	19.0	15.6%
Diesel Fuel	22.5	18.5	17.8%

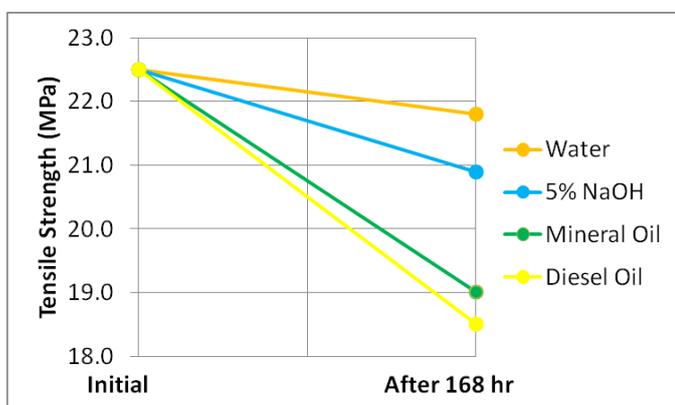


Figure 5: Tensile strength before and after swelling exposure

V. DISCUSSION

Swelling is strongly dependent on chemical affinity: oils and fuels caused the highest swelling due to higher solubility of plasticizers and polymer segments [4,7,8]. Water produced minimal swelling, consistent with PVC hydrophobicity [9].

Alkaline solution caused moderate swelling and slight tensile degradation, possibly due to surface hydrolysis [9]. Tensile strength decreased in proportion to swelling ratio, confirming mechanical softening [5,6]. Observed trends align with diffusion-controlled swelling models reported in previous studies [2,5,6]. The results emphasize the importance of selecting PVC hoses with proper formulation or barrier layers when used in chemically aggressive environments [10,11].

VI. CONCLUSION

Swelling of PVC hoses is strongly influenced by chemical medium, exposure time, and solvent-polymer interactions. Oils and fuels produce the greatest swelling and mechanical degradation; water causes minimal changes. Swelling reduces tensile strength, posing a risk for hose performance under load. Recommendations: For chemical applications involving oils or fuels, consider PVC formulations with enhanced plasticizer stabilization or barrier layers.

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