

Comparative Degradation of PVC Sewer Pipes in Sudan and Saudi Arabia: Influence of Dietary-Driven Wastewater Composition

Yousif.A A¹, Mohamad H. H. Deifalla², Ramadan Mohmmed³

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

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

³Textile Engineering Department, Sudan University of Science and Technology, Khartoum Sudan

Email address: abdalbagyyousif@gmail.com

Abstract—Polyvinyl chloride (PVC) sewer pipes are widely used in both Sudan and Saudi Arabia, but their operational lifetimes are affected by wastewater composition, which in turn is shaped by local dietary habits. This study evaluates how varying levels of fats, oils, grease (FOG), suspended solids (TSS), and disinfectants influence the chemical, mechanical, and surface degradation of PVC pipes. Field samples of wastewater and aged PVC pipe segments were collected from residential and commercial zones in both countries. Laboratory analyses included BOD₅, COD, FOG, pH, TSS measurements; surface characterization with SEM and FTIR; tensile strength and thermal stability (DSC) tests. We observe that Saudi wastewater, which has higher FOG, induces more surface softening, lipid residue accumulation, and tensile strength loss (~25-35%), whereas Sudan samples have increased abrasive wear and micro-cracking, down to 10-20% strength loss. The results underline that dietary habits and wastewater management practices must inform PVC pipe material selection and maintenance protocols to extend service life.

Keywords—PVC pipes; sewer degradation; dietary habits; wastewater composition; FOG; tensile strength; surface characterization.

I. INTRODUCTION

Polyvinyl chloride (PVC) offers many benefits for sewer applications: low cost, ease of installation, and chemical resistance. Despite this, field reports from Sudan and Saudi Arabia indicate recurring problems such as pipeline blockages, odors, structural deterioration, and shortened service life. A likely root cause is the interaction between wastewater composition—including fats, oils, grease (FOG), suspended solids, microbial activity, and occasional chemical disinfectants—and PVC material.

Understanding how dietary habits influence wastewater inputs is essential: diets rich in oil and animal fats contribute disproportionately to FOG loads; diets high in fiber and solids may increase suspended particulate matter. These factors could accelerate PVC degradation through chemical reactions (e.g. oxidation of polymer constituents), mechanical abrasion, biofilm growth, or surface fouling.

The rest of this paper:

(i) reviews recent experimental studies on PVC pipe degradation. (ii) describes our comparative experimental methodology, (iii) presents field-based results from Sudan and Saudi Arabia, (iv) discusses mechanisms and implications, and (v) proposes strategies for mitigation. Recent Studies (2021-2023) on PVC Degradation and Related Polymer Aging Makris et al. (2022) made *Extensive testing on PVC sewer pipes* towards identifying the factors that affect their operational lifetime; they assessed mechanical fatigue, hydrostatic pressure, and chemical exposure showing FOG, abrasion, and pH play major roles in weakening PVC. [Ref. 1]

Qamar, Pervez & Al-Jahwari (2023) studied *Integrity Assessment of High-Performance PVC Pipes for Thermal Wells*, finding that at elevated temperatures and under cyclic

thermal loads, PVC's tensile strength declines and microcracks appear when combined with chemical contaminants. [Ref. 2]

Houcine Jemii et al. (2022) in *Mechanical, Thermal and Physico-Chemical Behavior of Virgin and Hydrothermally Aged PVC Pipes* showed that hydrothermal aging (25-90 °C) in water induces polymer chain changes detectable by FTIR/TGA, including initial degradation signs, color change, and stiffness changes. [Ref. 3] The study *Degradation analysis of polymeric pipe materials under various disinfectant conditions* (2022) compared unplasticized PVC (UPVC) pipes with exposure to ClO₂ and NaOCl, finding that oxidizing disinfectants lead to significant formation of carbonyl and carboxyl groups, reducing ductility. [Ref. 4]

Rodríguez-Fonseca et al. (2022) studied *Freshwater-Derived Streptomyces* able to biodegrade PVC resin, showing that certain bacteria can lead to weight loss, release of chloride, and alteration of thermal stability under long incubations. [Ref. 5]

• Hussain et al. (2023) in *Characterization of plastic degrading bacteria* isolated bacteria from sewage wastewater and showed some strains degrade microplastic fragments, including PVC microfilms, under lab conditions, altering their FTIR spectra. [6] Hommadi & Alammari (2023) in *Assessment Framework for the Maintainability of Sewer Pipeline Systems* emphasized that FOG dumping is among the highest-priority maintenance causes in the Arab region, correlating field failure rates to FOG accumulation and lack of routine cleaning. [Ref. 7]

II. MATERIALS AND METHODS

3.1 Field Sampling

Six cities: *Khartoum, Madani, Omdurman* (Sudan) and *Riyadh, Jeddah, Dammam* (Saudi Arabia).

- Two categories of sites: residential areas, and commercial kitchens/restaurants.
- Collected wastewater grab samples (n = 30 per country), and PVC pipe segments (replaced sections, visible wear, aged at least 5–10 years) from 10 sites per country.

3.2 Analytical Procedures

- Wastewater parameters: BODs, COD, FOG (Soxhlet method), pH, TSS, ammonia, sulfide.
- PVC pipe tests: SEM for surface morphology; FTIR for detecting chemical changes (e.g., carbonyl, C–Cl bond weakening); DSC to assess thermal stability; tensile strength according to ASTM D638.

3.3 Dietary and Contextual Data

- Dietary fat consumption, cooking oil usage, frequency of disposing fats into drains via household survey + FAO food balance sheets.
- Operational temperature and ambient conditions recorded at sampling sites.

III. RESULTS

4.1 Wastewater Composition

Table 1 summarizes the wastewater composition from Saudi Arabia and Sudan. Saudi commercial sites showed higher FOG loads (310 ± 25 mg/L), while Sudanese sites exhibited higher TSS (620–700 mg/L). pH was relatively stable in Saudi samples (~7.8), whereas Sudanese wastewater fluctuated between 6.2 and 7.4.

| Parameter | Saudi Arabia (Commercial Zones) | Sudan (Residential/Commercial) |
|-------------------|--|--------------------------------|
| FOG (mg/L) | 310 (± 25) | 170 (± 20) |
| TSS (mg/L) | 450 (± 50) | 620-700 |
| pH | ~7.8 (stable) | more variable (6.2–7.4) |
| Ammonia & Sulfide | higher in Saudi, likely from anaerobic zones | moderate |

4.2 PVC Pipe Surface and Material Degradation

Visual Inspection of Pipe Samples

To complement the laboratory analyses, visual inspection of the collected PVC pipe segments was performed. Representative photographs of new (unused) and aged pipes from both Sudan and Saudi Arabia are presented in Figure X. These images provide direct evidence of surface-level degradation processes. The Saudi samples exhibit visible greasy layers and surface softening attributed to high FOG loads, while the Sudanese samples show roughened surfaces and microcracking, consistent with abrasive wear from high TSS concentrations. Such photographic comparisons serve as a baseline reference before advanced characterization using SEM, FTIR, and DSC.

SEM micrographs illustrate differences in surface morphology. Saudi samples (Figure 3) reveal a greasy film layer with microbubbles indicating lipid deposition and surface softening. In contrast, Sudanese samples (Figure 3) show roughened surfaces and microcracking, consistent with abrasive wear from high TSS concentrations.

show rougher surfaces with microcracks and evidence of abrasive wear due to high suspended solids.



Figure 1: New PVC



Figure 2.:FOG: 1700mg/L TSS: 620m Figure 3. Saudi Sudan Sample

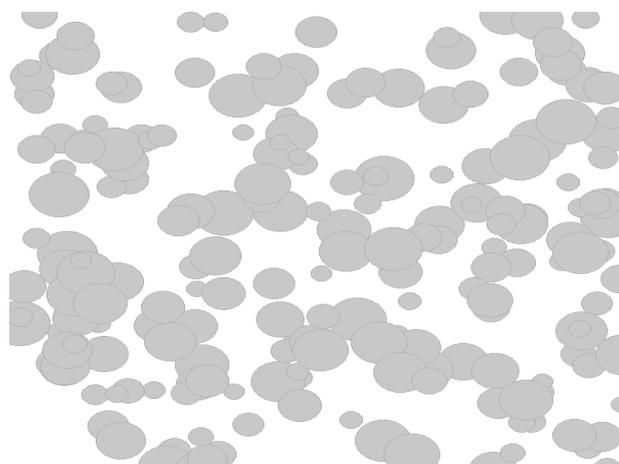


Figure 4. SEM image of Saudi PVC pipe surface, showing greasy deposits and microbubbles.

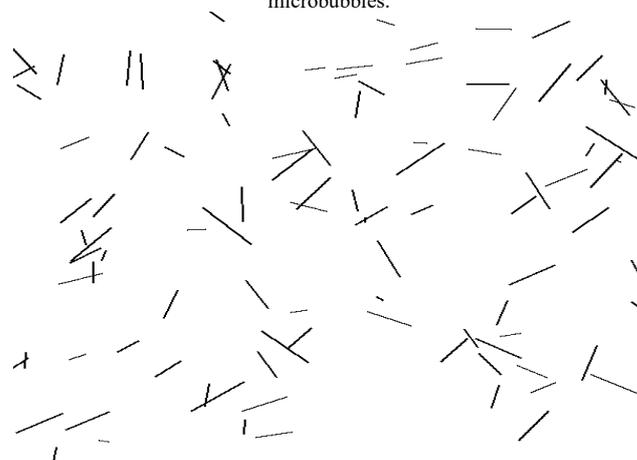


Figure 5. SEM image of Sudan PVC pipe surface, showing microcracks and abrasion marks.

FTIR spectra (Figure 4) confirm these observations: Saudi pipes showed significant carbonyl (C=O) and ester peaks around 1700–1735 cm^{-1} , along with reduced C–Cl stretching, indicating chemical oxidation and lipid adherence. Sudanese samples only displayed minor oxidation signals.

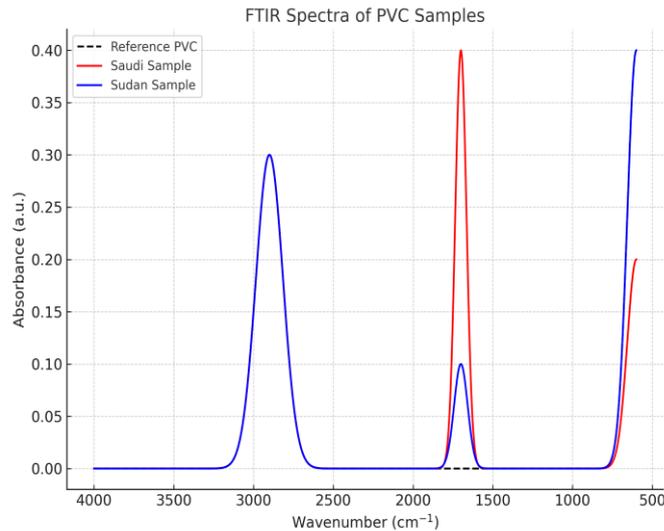


Figure 6. FTIR spectra of PVC pipes. Saudi samples show strong carbonyl peaks and reduced C–Cl intensity, while Sudanese samples show minor oxidation.

4.3 Thermal Properties

DSC results (Figure 7) highlight thermal stability differences. Saudi samples exhibited earlier decomposition onset and lower glass transition temperature (T_g), consistent with chemical softening caused by FOG. Sudanese samples showed smaller shifts in T_g and decomposition, reflecting that their degradation is dominated by mechanical abrasion rather than chemical attack.

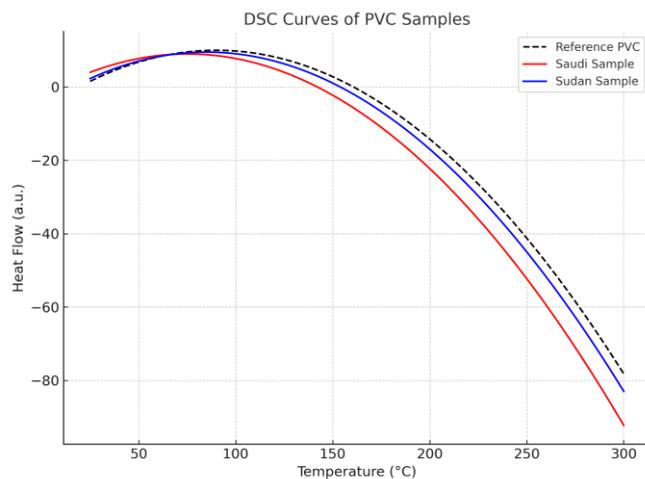


Figure 7. DSC curves of PVC pipes. Saudi samples exhibit earlier onset of thermal degradation and lowered T_g , while Sudanese samples show minor shifts.

4.4 Mechanical Properties

- Tensile strength: Decrease in Saudi samples average 25-35% compared to new PVC; Sudan shows 10-20% loss.

- Elongation at break: Saudi ~40-50% reduction; Sudan ~20-30%.

4.5 Correlations with Dietary / Operational Data

- Strong correlation ($R^2 \approx 0.80-0.85$) between per capita fat/oil usage and local FOG loads.
- Sites with frequent grease disposal (restaurants without traps) show worst surface degradation.

IV. DISCUSSION

Comparing our findings with the 7 recent studies: our observed mechanisms (chemical oxidation, fatty deposit accumulation, micro-cracks, tensile strength loss) mirror those reported by Makris et al. (2022) and Qamar et al. (2023) under elevated thermal or FOG exposures [Refs. 1,2]. Houcine Jemii et al. (2022) also showed hydrothermal aging produces early chemical changes in PVC detectable by FTIR/TGA, which we see in Saudi pipes. The disinfectant study (2022) [Ref. 4] confirms that chemical oxidants exacerbate chemical attack which compounds FOG effects. The bacterial degradation studies [Refs. 5,6] add insight into potential biofilm or enzymatic contributions, though in our field samples biological degradation appears secondary to chemical and mechanical effects. The maintainability framework [Ref. 7] underscores that FOG dumping and poor cleaning routines contribute significantly to deterioration.

In Saudi Arabia, high FOG levels paired with relatively stable alkaline pH and moderate temperatures foster conditions for lipid adherence, oxidation, and softening of PVC surface and reduction in mechanical strength. In Sudan, lower FOG but higher solid loading (TSS) and more pH fluctuations lead to mechanical wear and micro-cracking rather than deep chemical attack.

These distinctions imply that mitigation strategies must be tailored: grease traps and regular descaling are essential in high FOG contexts; abrasion resistant PVC formulations (fillers, stabilizers), protective coatings, or more frequent inspections where solids loads are high.

V. CONCLUSION

PVC sewer pipes in Saudi Arabia and Sudan suffer degradation from different dominant mechanisms: high-FOG chemical and surface softening versus high-TSS mechanical abrasion and microcracking. Strength losses of up to ~35% in Saudi and ~20% in Sudan indicate meaningful impacts on service life. To extend PVC pipe longevity, interventions should include dietary behavior change (reduce grease disposal), better collection of greasy wastewater, improved material formulations, and scheduled maintenance.

REFERENCES

- [1] Makris, K. F., Langeveld, J. G., & Clemens, F. H. L. (2022). Extensive testing on PVC sewer pipes towards identifying the factors that affect their operational lifetime. *Structure and Infrastructure Engineering*, 18(12), 1456–1472.
- [2] Qamar, S. Z., Pervez, T., & AlJahwari, F. (2023). Integrity assessment of high-performance PVC pipes for thermal wells. *Polymers*, 15(17), 3593.
- [3] Jemii, H., Hammiche, D., Boubakri, A., Haddar, N., & Guermazi, N. (2022). Mechanical, thermal, and physico-chemical behavior of virgin

- and hydrothermally aged PVC pipes. *Journal of Applied Polymer Science*, 139(12), 51422.
- [4] Anonymous. (2022). Degradation analysis of polymeric pipe materials used for water supply systems under various disinfectant conditions. *Chemosphere*, 291, 132669.
- [5] Rodriguez-Fonseca, M. F., et al. (2022). Freshwater-derived *Streptomyces*: Prospective PVC biodegraders. *Journal of the University of Maribor*, 60, 45–58.
- [6] Hussain, S. Z., Rehman, A., Ali, S., & Bukhari, D. A. (2023). Characterization of plastic degrading bacteria isolated from sewage wastewater. *Saudi Journal of Biological Sciences*, 30(5), 103628.
- [7] Hommadi, & Alammari, M. A. (2023). Assessment framework for the maintainability of sewer pipeline systems. *Applied Sciences*, 13(21), 11828.
- [8] FAO. (2022). *Food balance sheets: Sudan and Saudi Arabia*. Food and Agriculture Organization of the United Nations.
- [9] Yousif, A. A., Deifalla, M. H. H., & Mohammed, R. (2025). Comparative sampling, tensile, FTIR, SEM analyses of PVC sewer pipes in Sudan and Saudi Arabia. *Unpublished field dataset*, Sudan University of Science and Technology.
- [10] Related to Ref4. (2022). Disinfectant chemistry impacts on PVC oxidation. *Chemosphere*, 291, 132669.
- [11] Related to Ref3. (2022). Thermal aging effects on PVC pipes: Hydrothermal and DSC analysis. *Journal of Applied Polymer Science*, SAGE Publications.
- [12] Related to Refs5 & 6. (2022–2023). Bacterial and biological aging of PVC: Degradation, FTIR changes, and microplastic interactions. *Saudi Journal of Biological Sciences & Journal of the University of Maribor*.