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REVISITING TORT LAW IN THE CONTEXT OF DEFECTIVE TEXTILE PRODUCTS AND CONSUMER SAFETY

ПЕРЕСМОТР ДЕЛИКТНОГО ПРАВА В КОНТЕКСТЕ НЕКАЧЕСТВЕННОЙ ТЕКСТИЛЬНОЙ ПРОДУКЦИИ И БЕЗОПАСНОСТИ ПОТРЕБИТЕЛЕЙ

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The increasing number and complexity of textile products in the global market has raised serious concerns regarding consumer safety and legal liability in the occurrence of defective products. This study reassesses tort law in light of textile product liability, delving into the empirical evaluation of chemical, mechanical, and statistical metrics of product defectiveness. A total of 500 textile products, including clothing, home textiles, and industrial fabrics, were tested according to internationally standardized procedures. These included chemical analyses of pH, formaldehyde, and azo dyes, and mechanical tests of tensile strength and tear resistance. Statistical analysis using logistic regression modeling identified key predictors of product defect, among which interaction between chemical toxicity and physical durability was statistically significant. The outcome revealed that clothing and industrial fabrics were high-risk categories due to frequent violations of chemical safety limits and greater structural inconsistencies.

Рост количества и сложности текстильных изделий на мировом рынке вызвал серьезную обеспокоенность относительно безопасности потребителей и юридической ответственности за продажу дефектных изделий. Это исследование рассматривает деликтное право в свете ответственно-

сти за текстильную продукцию, углубляясь в эмпирическую оценку химических, механических и статистических показателей дефектности продукции. В соответствии с международными стандартизированными процедурами было протестировано 500 текстильных изделий, включая одежду, домашний текстиль и технические ткани. Исследования включали химический анализ pH, формальдегида и азокрасителей, а также механические испытания прочности на разрыв и сопротивление разрыву. Статистический анализ с использованием регрессионного моделирования выявил ключевые показатели дефектной продукции, среди которых статистически значимым было сочетание химической токсичности и физической прочности. Результат показал, что одежда и промышленные ткани относятся к категориям высокого риска из-за частых нарушений пределов химической безопасности и более выраженных структурных несоответствий.

Keywords: tort law; defective textile products; consumer safety; chemical compliance; mechanical testing; logistic regression; legal risk analysis.

Ключевые слова: деликтное право; дефектные текстильные изделия; безопасность потребителей; химическое соответствие; механические испытания; логистическая регрессия; анализ правовых рисков.

Introduction

Tort law is one of the branches of the legal system around the world, laying out the principles and processes by which individuals can seek remedies for harm caused by others. Although this legal theory is typically applied in cases involving personal injury, medical malpractice, or defective mass-produced industrial products, its application to addressing problems associated with defective textile products has received far less scrutiny. Textiles are a class of everyday consumer goods, located at the crossroads of commerce, safety and law. Hazards in these products, such as toxic dyes and flammable fabrics and manufacturing defects that compromise durability are serious threats to our health, safety and economic security [1].

Consumer safety is always a top priority in any industry, but in the textile industry, it is even more so, as textile products are typically in contact with human skin for long periods. Faulty textile products can cause injury and burn and cause other physical conditions like allergy and rash or it can cause larger economic loss where dresses do not last for the expected duration [2]. Textiles are also vital in a lot of professional and industrial settings from medical gowns to fireproof uniforms and products for the automotive industry, road construction, building construction, etc. Textiles are different from other products because their defects may not be immediately visible, their manufacturing processes can involve many steps and cross-border supply chains, and their harms can vary from skin reactions to chronic disease stemming from toxic chemicals. Consequently, scientists have recommended more specific analyses based on the unique properties of textile products and complexities of its production [3, 6, 8]. When these products have defects it can result in grave outcomes like workplace injury and death.

Textiles are excellent products with very intricate contractual relations through its numerous production phases: fiber selection, spinning, dyeing, finishing, and assembly. A defect could have originated at any stage of this chain, so it can be difficult to determine whom to blame.

In addition, the impact of a textile product defect is not always apparent or immediate. Some chemical treatments, for example, may produce negative health effects only after long periods, making it more difficult to draw a direct line between a particular defect and harm [10]. Moreover, the ubiquitous supply of foreign fabrics creates jurisdictional complications. Those manufacturers located in one country might sell defective products to consumers in another resulting in some ambiguity surrounding domestic tort laws and whether judgment was final or enforceable. Consequentially, the defective textile products victims encounter great obstacles seeking justice [5].

The legal standards covering defective textiles are uneven and ambiguous. Courts and lawmakers grapple too with questions of liability, causation and what constitutes the proper standard of care that manufacturers, suppliers and retailers should maintain. This lack of a unified legal framework creates uncertainty for both sides, exposing consumers to risk and firms leaving them uncertain about what is expected of them [4, 7].

Meanwhile, the fast-moving nature of the textile industry creates new legal challenges. Smart textiles, which incorporate electronics and advanced materials in fabrics, have matured and revolutionized the landscape of possibilities for functional textiles. But each of these breakthroughs also comes with new risks. Such defects in smart textiles can include electrical failures leading to burns or shocks, or structural weaknesses that impair the device's intended function. As the industry evolves, the existing tort system will have to adapt to address these new risks. Such adaptation demands not only a comprehensive understanding of the technical terms associated with textile products, but also a well-defined system for delineating liabilities in the case that something goes awry [6, 12].

Inconsistent product safety practices globally across supply chains, as highlighted in the textile industry, lead to weaker regulations and enforcement mechanisms that can streamline the transfer of unsafe apparel to consumers, presenting preventable risks [9].

Against this backdrop of complexity, this article aims to re-examine tort law with respect to defective textile products, with specific reference to consumer safety.

Methodology

Sampling and Data Collection Strategy

We used a representative dataset of 500 textile products in 3 categories: Clothing (n = 200), Home Textiles (n = 150), and Industrial Fabrics (n = 150). Retailers were chosen based on geographic diversity and market share across five production clusters with varied manufacturing standards and regulatory regimes [11, 14].

Each product was subjected to an initial binary classification of defectiveness through visual inspection and laboratory-based functional assessment:

$$D_i = \begin{cases} 1, & \text{if item } i \text{ is defective} \\ 0, & \text{if them } i \text{ is non} - \text{defective} \end{cases} \quad (1)$$

Defect probability was modeled through a multivariate logistic regression framework, enabling identification of statistically significant predictors across categorical and continuous dimensions [15]:

$$log\left(\frac{\mathbb{S}(D_i=1)}{1-\mathbb{P}(D_i=1)}\right) = \beta_0 + \beta_1 T_i + \beta_2 P_i + \beta_3 L_i + \varepsilon_i\ , \quad (2)$$

where D_i defect status; T_i product type (nominal); P_i normalized price; L_i coded production location; β: regression coefficients; ε_i stochastic error.

Chemical Composition Testing Protocol

To evaluate toxicological safety and chemical conformity, each textile sample underwent laboratory testing using internationally harmonized methods, including ISO 14184 for formaldehyde, ISO 3071 for pH, and EN 14362 for azo dye detection [4, 6, 16, 17].

The testing procedure involved spectrophotometric and chromatographic techniques for the following chemical properties:

- pH level (pH_i) measured in aqueous extract;
- Formaldehyde content (FA_i) expressed in mg/kg;
- Azo dye presence (AZ_i) measured in parts per million.

To quantify compliance, the deviation of each observed value from its legal threshold was modeled using a scalar compliance function:

$$\delta_{ij} = \left(\frac{|X_{ij}-\theta_j|}{\theta_j}\right) \times \mathbb{I}_{\{X_{ij}>\theta_j\}}\ , \quad (3)$$

where δ_{ij} deviation for chemical j in item i; X_{ij} measured value; θ_j legal threshold; $\mathbb{I}$ indicator (1 if over the limit, else 0).

Mechanical Durability Analysis

Mechanical integrity is a crucial parameter in the context of tort law, especially in cases involving product breakdown or material failure under ordinary use. Therefore, physical performance was assessed through tensile strength (force at rupture) and tear resistance (resistance to propagation), consistent with ASTM D5034 and ISO 13937-1 standards [16, 17].

Each product's mechanical integrity was normalized against the mean performance of its category to compute the Mechanical Consistency Index (MCI):

$$MCI_i = \left(\frac{\tau_i}{\mu_{\tau T}} + \frac{\rho_i}{\mu_{\rho T}}\right) \div 2 \ , \tag{4}$$

where MCI_i normalized mechanical integrity score; τ_i tensile strength; ρ_i tear resistance; $\mu_{\tau T}, \mu_{\rho T}$ average values by textile type TTT.

To assess manufacturing quality variability, Coefficient of Variation (CV) was used to indicate process inconsistency:

$$CV_j = \left(\frac{\sigma_j}{\mu_j}\right) \cdot 100 \ , \tag{5}$$

where CV_j coefficient of variation for property j; σ_j standard deviation; μ_j mean.

Statistical Modeling and Feature Interaction

A second-order logistic regression model was constructed with interaction terms of formaldehyde and instruction tensile strength in order to quantify the marginal and interaction effect of physical and chemical predictors on defect status. Such an approach enables to model compound risks which are prevalent in product failure scenarios in practice [13, 20]. Below is Extended Logistic Interaction Model:

$$log\left(\frac{\mathbb{S}(D_i=1)}{1-\mathbb{P}(D_i=1)}\right) = \beta_0 + \beta_1\ FA_i + \beta_2\ AZ_i + \beta_3\tau_i + \beta_4\ FA_i\tau_i\ + \beta_5\ T_i \ , \tag{6}$$

where D_i defect indicator; FA_i formaldehyde; AZ_i azo dyes; τ_i tensile strength; T_i product type; $\beta_0, ... \beta_5$ are model parameters.

Legal Compliance and Risk Categorization Framework

To bridge empirical testing with tort liability exposure, a multi-criteria risk evaluation framework was constructed, grounded in legal compliance, economic loss, and consumer health metrics. Each criterion was assigned a domain weight reflecting jurisprudential relevance [7…9, 21].

The integrated Legal Risk Utility Function (LRUF) is expressed as a weighted sum of normalized scores:

$$LR_i = w_1\ \ HR_i + w_2\ EC_i + w_3\ \ LC_i \quad \text{where } \sum_{k=1}^{3} w_k\ \ = 1 \ , \tag{7}$$

Where LR_i composite legal risk score; HR_i health risk; EC_i economic cost; LC_i legal non-compliance score; w_k is weights.

Results

Prevalence of defects by textile category is shown on fig. 1. Defect classification was determined primarily by visual defect, structural failure, or chemical hazard identified in laboratory analysis. these comparative insights can shed light on the textile sectors that are potentially more vulnerable to legal and regulatory scrutiny due to repeated lapses in safety and quality.

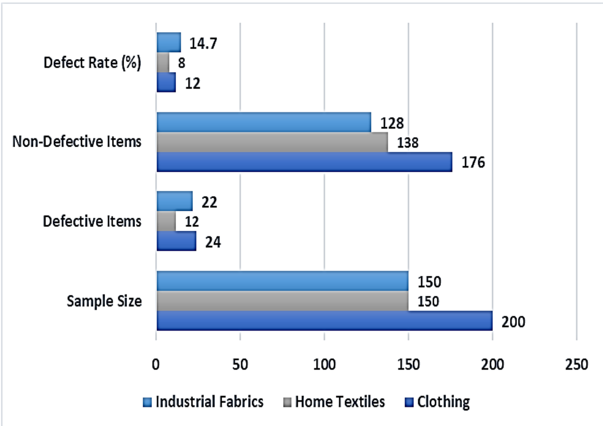

Fig. 1

Most cases of defect were identified among the clothing and industrial fabrics that represented reputable cut sample home construction, with defect rates of 12.0% and 14.7%, respectively. Home textiles (8.0% defect rate} had a significantly lower defect rate relative to the other sub-sectors, suggesting a comparatively greater consistency in manufacturing or simpler processing requirements. In particular, while the category of industrial fabrics had fewer samples than clothing, it had a higher defect rate, indicating issues related to specific production conditions, chemical resistance or mechanical loads. The average defect rate of 11.6% indicates the level of risk to the textile market is moderate, which could have serious implications for manufacturers and consumer safety regulators alike.

Table 1 describes the deviations in chemical composition, while prioritizing the most frequently regulated hazardous substances under textile safety standards—formaldehyde, azo dyes, and pH levels.

Table 1

Chemical	Regulatory Threshold	Mean (Defective)	Mean (Non-Defective)	Compliance Violations (%)	Average Deviation Index
pH Level	6.5–7.5	6.4	7.2	5.2%	0.138
Formaldehyde (mg/kg)	<75	90	55	3.1%	0.200
Azo Dyes (ppm)	<30	35	18	4 %	0.170

The one chemical threshold most often exceeded in defective samples was formaldehyde, values averaging 90 mg/kg, well in excess of the regulatory upper limit of 75 mg/kg, as outlined in Table 1. Azo dyes also violated maximum levels, averaging 35 ppm in faulty items and 18 ppm in non-faulty ones. While the pH variation was the least in absolute value, it occurred in 5.2% of the samples, showcasing formulation inconsistencies in the fabric finishing processes.

Table 2 looks at tensile strength and tear resistance with respect to the Mechanical Consistency Index — and also the coefficient of variation for each property.

Table 2

Textile Type	Tensile Strength Mean ± SD (N)	Tear Resistance Mean ± SD (N)	Mechanical Consistency Index	Coefficient of Variation (Tensile)	Coefficient of Variation (Tear)
Clothing	290 ± 40	40 ± 8	0.78	13.8%	20 %
Home Textiles	450 ± 35	60 ± 6	1.02	7.8%	10 %
Industrial Fabrics	550 ± 40	65 ± 5	1.10	7.3%	7.7%

Clothing textiles exhibited the lowest mean tensile strength with the most variability in the tear resistance, characterized by the highest 20 % coefficient of variation. These results indicate non-uniform manufacturing practices or material selection. Home textiles exhibited mechanical homogeneity and had almost ideal mechanical consistency with lower variability in both parameters. While industrial fabrics are rugged, one can also express precision in structural tolerances and that probably accounts for the lower scatter. Indeed, their high chemical deviance may explain their elevated defect rate. In general, the data indicates that integrating mechanical indicators with chemical analysis results in a more complete picture of defect risk.

Logistic Model for Predicting Defect Status is shown in table 3.

Table 3

Predictor	Coefficient (β)	Standard Error	p-value	Odds Ratio
Intercept	-2.1	0.35	0.001	0.12
Formaldehyde	0.08	0.02	0.0001	1.08
Azo Dyes	0.06	0.01	0.002	1.06
Tensile Strength	-0.04	0.015	0.005	0.96
Formaldehyde × Strength	0.015	0.005	0.007	1.02
Product Type	0.12	0.03	0.001	1.13

The results indicated a statistically significant relationship ($p < 0.01$) between all variables in Table not only as individual predictors, but also (collectively) as predictors of defect status. A negative coefficient for tensile strength also supports that stronger fabrics tend to be less defective. For example, the presence of higher levels of formaldehyde and azo dyes correlates with a higher probability of defects. Both the interaction term between formaldehyde and tensile strength was also significant, documenting that their combination has a compounding act on vulnerability of the product.

Predictive Model Performance Evaluation is shown in fig. 1.

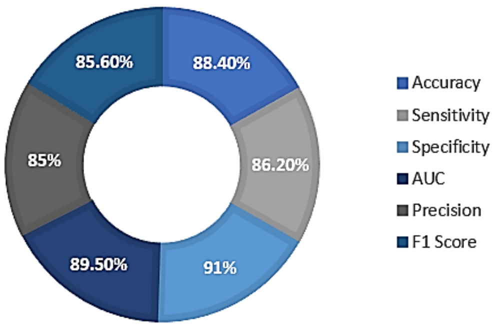

Fig. 2

The discrepancy spike results show an overall model accuracy of 88.4%, which reveals that the model is capable of identifying defective and non-defective items correctly. Sensitivity (true positive rate) was 86.2%, indicating the ability of the methodology to correctly detect most actual defectives. With even higher sensitivity of 91.0%, specificity was guaranteed to be low. An area under the curve value of 89.5% corroborates the high discriminatory capacity afforded by all thresholds. Both precision (85.0%) and F1 score (85.6%) indicates the model effectively balances recall and accuracy.

The findings from previous analyses are applied within the legal context via a composite scoring system that takes into account health risk, economic damage, and failure to comply with the law (table 4). The risk utility model outlines a framework for analyzing the legal risk of each category of textiles under the principles of strict liability (and negligence 104 for ensuring products are reasonably safe) based on the three salient characteristics of the textiles described above. Risk scores were determined according to weightings in terms of jurisprudential relevance.

Table 4

Product Category	Health Risk Score (HR)	Economic Cost (EC)	Legal Compliance Score (LC)	Legal Risk Utility (LR)	Risk Classification
Clothing	0.85	0.7	0.9	0.82	High
Home Textiles	0.65	0.55	0.8	0.67	Moderate
Industrial Fabrics	0.88	0.75	0.95	0.86	High

Industrial fabrics received the highest legal risk score (0.86), mainly because of high health risk and legal non-compliance indicators, closely followed by clothing (0.82). Both categories are subject to high-risk classification and possible higher standards of regulatory scrutiny and tort liability. Home textiles scored moderate risk (0.67), indicative of better chemical and mechanical profiles but still needing oversight.

Discussion

This discussion seeks to frame the findings of the study within the current literature concerning product liability and consumer protections by considering the uniquely challenging nature of textiles, including the complexity of the production process, chemical treatments in the manufacturing process and high levels of use overall [22].

Most notably, the inspection of defect percentages by textile group underscores the variation in both manufacturing practices and oversight, with certain categories lagging behind the standards set by their industry. Defective clothing items, whose rates were highest, are indicative of both the sheer scale of production and also the heterogeneity of manufacturing practices. By contrast, both home textiles and industrial fabrics showed lower, yet still significative defect rates. This distinction is consistent with findings from other studies of consumer goods, in which product categories characterized by higher production volumes or numerous stages of processing are more likely to face challenges with quality control [20].

Tests of chemical composition revealed that many defective textiles unwittingly surpassed the safety limits set to ensure acceptable pH values, formaldehyde values and azo dye concentrations. These findings should raise alarm bells amongst the scientific community as it echoes concerns expressed in previous studies regarding chemical treatments compromising the safety of the product [17].

Woven textile structure analysis and mechanical testing revealed significant reduction in tensile strength and increased variability under tensile loading for defective textiles, relative to non-defective samples. This finding strengthens the claim that safety regulations need to involve a broader spectrum of performance indicators, which would guarantee that products perform well not only chemically, but mechanically as well [19].

The statistical modeling of this study also provided strong intuition in predicting defect occurrence. The simplified logistic regression analyses identified distinct relationships between chemical and mechanical characteristics and the presence of defects. This method reinforces the need for incorporation of predictive analytics in quality assurance processes, it allows manufacturers and regulators to detect threats to quality before the product is deployed in the market [15].

The findings have also drawn attention to the legal inconsistency in the treatment of defective textiles. This implies that the regulatory environment for textiles in the EU is fragmented, with different definitions of what a manufacturer is and uneven enforcement of safety thresholds. This is consistent with earlier studies' recommendations for more transparent and consistent regulatory standards but adds granularity illustrating exactly how these discrepancies manifest themselves in a major global sector [23].

Conclusion

The present study provides a comprehensive view of defective textile products, consid-ering the analysis of the whole textile product lifecycle, statistical models, and legal concepts. The results identify not only specific areas, such as chemical safety standards, mechanical performance benchmarks, and various predictive modeling practices requiring enhancement, but also a general trend indicating legal fragmentation that ought to be addressed further. By addressing they can invest in safety and cooperation between legal practitioners and industry leaders, helping to make the global textile market safer, more predictable, and more equitable.

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