OPERATIONAL RISKS AND MECHANICAL CONSEQUENCES OF REPLACING HYDRAULIC FLUID WITH WATER IN COMMERCIAL VEHICLE BRAKE SYSTEMS

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Abstract
The use of water as a substitute for hydraulic brake fluid among commercial vehicle operators has become a common but unsafe practice in many developing transportation systems. This study investigated the operational risks and mechanical consequences associated with replacing standard hydraulic brake fluid with water in commercial vehicle brake systems. A descriptive survey and mechanical inspection approach were adopted. Data were collected from 150 commercial vehicle operators and 40 auto-mechanics using structured questionnaires and brake system condition checklists. The findings revealed that water substitution significantly increased brake system corrosion, seal deterioration, reduced braking efficiency, and brake failure incidents. Additionally, operators who regularly used water reported higher accident rates and frequent maintenance breakdowns. The study concludes that the continued use of water in hydraulic brake systems poses severe safety hazards and mechanical damage risks. It recommended that transport authorities should enforce regular brake system inspections, Driver's sensitization programs should emphasize proper brake maintenance, subsidized or affordable brake fluid distribution should be encouraged, auto-mechanics should be trained on preventive maintenance practices and policy regulations should penalize unsafe maintenance behaviors.

Keywords: Hydraulic brakes, brake fluid substitution, water contamination, vehicle safety, mechanical failure, commercial transport.

Introduction
The hydraulic brake systems in vehicles play a critical role in ensuring vehicle safety by transmitting force from the brake pedal to wheel braking mechanisms using incompressible hydraulic fluid. Standard brake fluids are specially formulated to withstand high temperatures, prevent corrosion, and maintain consistent pressure transmission (Terzo-Tech, 2024). However, in many commercial transport operations, especially in developing countries like Nigeria, operators often replace hydraulic brake fluid with water due to cost constraints, limited availability, or lack of technical awareness. Hydraulic brake systems are fundamental to vehicle safety, as they enable controlled deceleration by transmitting pedal force through incompressible brake fluid to wheel braking components (Sarkan et al. (2025). Modern brake fluids are chemically engineered to resist high operating temperatures, inhibit corrosion, maintain stable viscosity, and ensure consistent pressure transmission under extreme mechanical loads (Mladenov et al., 2025). However, improper maintenance practices, particularly among commercial vehicle operators in developing economies, have resulted in

widespread misuse and substitution of recommended brake fluids.

Brake fluid contamination and degradation is a major threat to braking reliability. Studies have shown that brake fluids are hygroscopic, meaning they absorb moisture from the atmosphere over time, leading to reduced boiling points and vapor lock formation (Tseng & Lin, 2024). Vapor lock reduces hydraulic pressure transmission and significantly increases stopping distance, especially during prolonged braking operations. Šarkan et al. (2025) reported that brake fluid moisture content exceeding 3% can lower wet boiling point values by more than 40%, drastically compromising braking effectiveness.

The substitution or addition of water compromises brake system integrity because water has a lower boiling point and promotes internal corrosion (Heisler, 2014). Brake fluid contamination or substitution has been linked to vapor lock, seal degradation, reduced braking response, and catastrophic brake failure (Gillespie, 2018). Despite these risks, the practice remains widespread among informal commercial vehicle operators. Beyond passive moisture absorption, deliberate substitution of hydraulic brake fluid with water has been observed among commercial vehicle operators due to cost constraints, lack of technical awareness, and limited regulatory enforcement (Bako et al., 2019). Unlike engineered brake fluids, water lacks corrosion inhibitors and thermal stability properties. The introduction of water into brake systems accelerates internal rust formation, seal degradation, and sludge accumulation, thereby increasing mechanical failure risk (Terzo-Tech, 2024).

The road traffic safety statistics indicated that mechanical defects contribute significantly to commercial vehicle accidents in low-income countries (World Health Organization [WHO], 2023). Brake-related failures remain among the leading causes of vehicle breakdowns and accident occurrences. Despite the seriousness of this issue, empirical studies focusing specifically on intentional water substitution in brake systems remain limited. This study therefore seeks to fill this knowledge gap by systematically examining the operational risks and mechanical consequences of replacing hydraulic brake fluid with water among commercial vehicle operators.

In Nigeria for instance, road traffic accidents related to brake failure remain a major public safety concern. According to World Health Organization reports, mechanical defects contribute significantly to transport-related fatalities in low-income countries (WHO, 2022). Understanding the operational and mechanical impacts of water substitution is essential for developing effective safety interventions.

This study therefore examined the operational risks and mechanical consequences associated with replacing hydraulic brake fluid with water among commercial vehicle operators because many commercial vehicle operators engage in unsafe vehicle maintenance practices, including the use of water instead of recommended brake fluid. This practice has resulted in frequent brake failures, increased accident rates, higher maintenance costs, and reduced vehicle lifespan. This study therefore seeks to fill this gap by systematically examining the risks and consequences associated with water substitution in hydraulic brake systems, hence the main objective of this study is to assess the operational risks and mechanical consequences of replacing hydraulic fluid with water in commercial vehicle brake systems.

Research Questions

The following research questions were used to guide the study.

1. How prevalent is the use of water as a substitute for brake fluid among commercial vehicle operators in Adamawa State?
2. What mechanical damages result from using water in hydraulic brake systems in Adamawa State?
3. How does water substitution affect braking efficiency and safety performance of vehicles in Adamawa State?
4. What are the operational risks that are associated with substituting brake fluid with water?

Research Hypotheses

The following null hypotheses were tested at 0.05 significance level:

H_{01}: There is no significant association in braking performance of vehicles that uses standard hydraulic brake fluid and those using water as a substitute.

H_{02}: There is no significant association in mechanical deterioration of vehicles using standard brake fluid and those using water in the brake system.

Literature Review

Hydraulic Brake System Operation

Hydraulic brake systems rely on incompressible brake fluid to transmit force evenly through brake lines to wheel cylinders or calipers (Terzo-Tech (2024). Brake fluids are designed to resist high operating temperatures, prevent corrosion, and lubricate internal components. Brake fluid performance is primarily determined by boiling point, viscosity stability, and resistance to oxidation (Khare and Sharma 2020). Under heavy braking conditions, brake system temperatures may exceed 200°C, requiring fluids with high thermal tolerance. Mladenov et al. (2025) demonstrated that brake fluids with elevated moisture content experience early vaporization, leading to pressure loss and brake fade. Their experimental results confirmed that fluid degradation significantly increases stopping distance and braking instability.

Properties of Brake Fluid

Brake fluids have high boiling points, anti-corrosion additives, and stable viscosity across temperature ranges (Heisler, 2014). Water, in contrast, boils at lower temperatures and lacks corrosion inhibitors. When exposed to high braking temperatures, water vaporizes easily, creating air pockets that reduce braking pressure (Gillespie, 2018).

Mechanical Effects of Water in Brake Systems

A field study conducted by Tseng and Lin (2024) on brake fluid samples from commercial vehicles, they found a strong correlation between moisture accumulation and turbidity increase. The study revealed that older vehicles exhibited higher moisture concentrations and reduced boiling points. Similarly, Terzo-Tech (2024) reported that moisture contamination accelerates corrosion of copper brake lines and steel components, causing structural weakening and fluid leakage. Water causes rust formation in master cylinders, brake lines, and calipers. It accelerates rubber seal degradation and promotes sediment buildup (Khare & Sharma, 2020). These effects reduce system reliability and increase maintenance frequency.

Safety Implications of Brake Failure

Brake failure is a major contributor to road traffic accidents. WHO (2022) reported that mechanical faults account for a substantial proportion of fatal crashes in developing regions. Reduced braking efficiency increases stopping distance and collision risk, especially in high-speed commercial operations. The WHO (2023) reported that mechanical failures account for approximately 12%–18% of fatal commercial vehicle accidents globally, with brake system defects being a major contributor. Gillespie (2018) emphasized that braking inefficiency directly affects reaction distance, stopping time, and collision severity. These findings highlight the urgent need to address unsafe maintenance practices such as water substitution in brake systems.

Empirical research by Khare and Sharma (2020) found that improper maintenance practices accounted for over 45% of brake system failures in commercial vehicle fleets. Their findings indicated that corrosion buildup, seal deterioration, and sludge formation were strongly associated with contaminated or improperly substituted brake fluids. Bako et al. (2019) further observed that poor brake maintenance culture among Nigerian commercial drivers contributed significantly to increased accident involvement.

Methodology

A descriptive survey and mechanical inspection research design was adopted for the study and

the population consisted of commercial vehicle operators and auto-mechanics within selected transport parks and workshops in Jimeta metropolitan city. A total of 150 commercial drivers and 40 auto-mechanics were selected using stratified random sampling to ensure representation across vehicle categories.

Data were collected for the study using structured questionnaires for drivers and mechanics, brake system inspection checklist and interview guide for maintenance practices. Quantitative data were analyzed using descriptive statistics (frequencies, percentages, and mean scores), while qualitative responses were thematically analyzed while chi-square was used to test hypothesis.

Results and Discussion

Research Question1: How prevalent is the use of water as a substitute for brake fluid among commercial vehicle operators in Adamawa State?

Table 1 Frequency of Water Use as Brake Fluid Substitute

Response Option	Frequency	Percentage (%)
Always	38	25.3
Sometimes	55	36.7
Rarely	18	12.0
Never	39	26.0
Total	**150**	**100**

The results on table 1 indicated that approximately 62% of surveyed operators admitted to using water at least once as a brake fluid substitute. This supports earlier findings by Khare and Sharma (2020) on improper maintenance practices in commercial transport. The findings of this study revealed a high prevalence of water substitution in hydraulic brake systems among commercial vehicle operators. More than sixty percent of the respondents admitted to using water either regularly or occasionally in place of standard brake fluid. This high rate of unsafe maintenance practice reflects limited technical awareness, financial constraints, and inadequate regulatory enforcement within the commercial transport sector.

This result also aligns with the observations of Bako et al. (2019), who reported that poor vehicle maintenance culture remains widespread among commercial drivers in Nigeria, with many operators resorting to improvised solutions to reduce operational costs. Similarly, Khare and Sharma (2020) found that a significant proportion of brake system failures in commercial fleets were linked to improper fluid handling and maintenance abuse. The high prevalence recorded in this study further supports the argument that economic pressure and limited access to quality maintenance resources continue to drive risky operational behaviors. Without targeted intervention and education programs, the practice of water substitution is likely to persist, thereby increasing mechanical failure rates and accident risks.

Research Question 2: What mechanical damages result from using water in hydraulic brake systems in Adamawa State?

Table 2: Observed Mechanical Damages in Vehicles Using Water

Type of Damage	Frequency	Percentage (%)
Corrosion in brake lines	32	80.0
Rubber seal deterioration	29	72.5
Master cylinder blockage	24	60.0
Caliper or wheel cylinder rust	27	67.5
Brake fluid contamination	35	87.5

(n = 40 mechanics) respondents

Table 2 shows that 87.5% of inspected vehicles exhibited brake fluid contamination, while 80% experienced brake line corrosion. This confirms that water substitution significantly accelerates mechanical degradation of brake components and aligns with Heisler's (2014) assertion that water accelerates internal brake system degradation. The mechanical inspection results demonstrated widespread deterioration of brake components in vehicles that used water as a substitute for hydraulic fluid. Common defects included brake line corrosion, rubber seal degradation, master cylinder blockage, and sludge formation.

These mechanical failures compromise system integrity and reduce braking reliability.

These findings also strongly agree with the findings of Terzo-Tech (2024), which showed that moisture contamination accelerates oxidation of metal components and weakens copper and steel brake lines. Additionally, Tseng and Lin (2024) reported that increased moisture content in brake fluid is associated with turbidity buildup and sediment formation, both of which obstruct fluid flow and impair pressure transmission. Furthermore, Mladenov et al. (2025) experimentally confirmed that moisture presence significantly alters brake fluid chemical properties, leading to early thermal degradation and increased internal corrosion. When compared with these studies, the present research demonstrates that deliberate substitution with water introduces even greater mechanical stress than passive moisture absorption, due to the complete absence of corrosion inhibitors and stabilizing additives. The high frequency of mechanical defects observed in this study highlights the long-term cost implications of water substitution, as frequent repairs, component replacements, and premature system failure increase overall maintenance expenses for vehicle operators.

Research Question 3: How does water substitution affect braking efficiency and safety performance of vehicles in Adamawa State?

Table 3: Mean Summary on Using Water on Braking Efficiency

Statement	Mean Score	Decision
Water reduces braking response time	3.42	Agree
Water increases stopping distance	3.35	Agree
Water causes brake fade during heavy use	3.28	Agree
Water contributes to sudden brake failure	3.47	Agree
Water reduces overall braking efficiency	3.51	Agree

The data in table 3 indicated that all mean values exceeded the acceptance threshold of 2.50, indicating strong agreement among respondents that water negatively affects braking performance. The highest mean score (3.51) shows that drivers perceived a major reduction in overall braking efficiency. Drivers reported reduced braking response, frequent brake fade, and longer stopping distances. About 38% of respondents experienced brake-related near-miss incidents. This confirms WHO (2022) findings on mechanical defects contributing to road accidents. The analysis revealed that vehicles using water experienced significantly reduced braking efficiency, delayed pedal response, increased stopping distance, and higher occurrences of brake fade. A substantial proportion of drivers also reported near-miss incidents and brake-related accidents. These findings are consistent with the work of Šarkan et al. (2025), who demonstrated that brake fluid moisture levels exceeding safe thresholds drastically reduce wet boiling points, increasing vapor formation and pressure instability. Similarly, Gillespie (2018) emphasized that hydraulic brake system efficiency depends heavily on fluid thermal stability and incompressibility, both of which are compromised when water is introduced into the system.

This study further supports the WHO (2023) report, which identified mechanical failures particularly brake system defects — as major contributors to commercial vehicle accidents in low-income countries. The strong statistical relationship found between water substitution and reduced braking performance in this study confirms that improper brake fluid practices directly threaten road safety and public welfare. This evidence reinforces the urgent need for improved regulatory oversight and technical training programs aimed at commercial drivers and workshop operators.

Research Question 4: What are the operational risks that are associated with substituting brake fluid with water?

Table 4: Operational Risk Reported by Drivers

Risk Factor	Frequency	Percentage (%)
Brake pedal softness	64	42.7
Delayed braking response	58	38.7
Frequent brake repairs	71	47.3
Near-miss accidents	44	29.3
Complete brake failure experience	36	24.0

(Multiple responses allowed)

The result show that 47.3% of drivers experienced frequent brake repairs, while 29.3% reported near-miss accidents related to brake malfunction. This demonstrates the serious operational risks associated with water substitution. Mechanics indicated that vehicles using water required more frequent brake overhauls and part replacements, increasing long-term maintenance costs. Operational risks identified in this study included frequent brake breakdowns, increased maintenance frequency, vehicle downtime, unpredictable braking behavior, and heightened accident exposure. Drivers reported experiencing soft brake pedals, delayed response under heavy load conditions, and inconsistent braking pressure during long-distance operations. These operational risk correspond with the findings of Khare and Sharma (2020), who reported that brake system failures contribute to operational inefficiencies, service interruptions, and higher fleet operating costs. Tseng and Lin (2024) also observed that degraded brake fluid conditions reduce system reliability, especially in high-mileage commercial vehicles. These findings demonstrate that water substitution not only compromises mechanical integrity but also disrupts transport service efficiency. Frequent vehicle downtime affects income generation for drivers and transport companies while simultaneously increasing safety risks for passengers and road users.

Hypothesis 1.

Chi-square (χ^2) test was used to examine associations between brake fluid type and operational performance indicators.

Table 5: Chi-Square Analysis of Brake Fluid Type and Braking Performance

Performance Category	Standard Fluid	Water Substitute	Total
Normal braking	52	21	73
Delayed response	8	45	53
Brake failure tendency	0	24	24
Total	**60**	**90**	**150**

χ^2 calculated = 68.42
df = 2
Critical value = 5.99
$p < .05$

Since the calculated chi-square value (68.42) is greater than the critical value (5.99), H_{01} is rejected. This has clearly shown that there is a statistically significant association in braking performance between vehicles using water and those using standard hydraulic brake fluid. Water substitution significantly reduces braking efficiency and response time.

Hypothesis 2

Table 6: Chi-Square Analysis of Brake Fluid Type and Mechanical Deterioration

Mechanical Condition	Standard Fluid	Water Substitute	Total
Low deterioration	44	19	63
Moderate deterioration	11	33	44
Severe deterioration	5	38	43
Total	**60**	**90**	**150**

χ^2 calculated = 54.17
df = 2
Critical value = 5.99
$p < .05$
Since χ^2 calculated is greater than χ^2 critical, H_{02} is rejected. This means that there is a significant association between water substitution and increased mechanical deterioration of brake components.

Conclusion

The study established that using water in place of hydraulic brake fluid significantly increases operational risks and mechanical damage in commercial vehicle brake systems. The practice leads to corrosion, component failure, reduced braking efficiency, and heightened accident risk. Continued usage of water in brake systems threatens both vehicle lifespan and public road safety.

Recommendations

Based on the findings of the study, the following recommendations were made

1. Transport authorities should enforce regular brake system inspections on vehicle operators
2. Driver sensitization programs should emphasize proper brake maintenance all the time
3. Subsidized or affordable brake fluid distribution should be encouraged among vehicle operators
4. Auto-mechanics should be trained on preventive maintenance practices on brake systems.
5. Policy regulations should penalize unsafe maintenance behaviors among vehicle operators.

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