

Evaluating the Economic and Social Impacts of Drinking Water Pollution in Ed Dueim City: An Empirical Study (2023–2025)

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Abstract:

This study aimed to assess the economic and social impacts of drinking water pollution in Edduiem City, which has recently experienced extensive population influxes due to the country's security situation. The study adopted a descriptive-analytical approach, utilizing a questionnaire as the primary tool for data collection from a simple random sample of (384) resident and displaced households. Data were processed and analyzed using the Statistical Package for the Social Sciences (SPSS). The study yielded several key results, most notably: nearly half of the study population (48.2%) relies on horse/donkey-drawn carts transporting water directly from the Nile without adequate treatment as their primary source of drinking water. Furthermore, water pollution causes a continuous financial drain on families; purchasing alternative water consumes approximately 22% of the total monthly income of low-income households. Waterborne pollution and its associated diseases also lead to a loss of work productivity, averaging 4 days per month for every household whose members contract an illness. The water crisis further entails severe social and psychological repercussions, chiefly continuous anxiety and psychological stress among heads of households, alongside the emergence of child school dropout trends to assist in water fetching. Statistical tests revealed significant differences in the magnitude of economic and social suffering, heavily favoring host families of internally displaced persons (IDPs) and low-income households. The study recommended the urgent need to enforce strict health surveillance over alternative water transport sources, distribute household water purifiers to families free of charge, support the main Edduiem water station with continuous electricity and purification chemicals, and direct the efforts of humanitarian organizations to provide free, sterilized water tanks in shelter centers and the hardest-hit neighborhoods to alleviate the financial and social burden on families.

Keywords: Drinking Water Pollution, Economic Cost, Social Impacts, Edduiem City, Environmental Justice

1. Introduction

Water represents the essential lifeline of existence and the fundamental driver for achieving sustainable development across its economic, social, and health dimensions. With accelerating population growth and escalating environmental pressures, securing clean and safe drinking water has emerged as one of the most complex challenges facing developing societies. Access to safe drinking water is not merely the fulfillment of a basic biological necessity; rather, it constitutes a foundational pillar for health security, as well as the economic and social stability of nations. Within

the Sudanese context, the water supply and purification system faces structural and environmental challenges of immense complexity, the intensity of which has compounded at an unprecedented rate during the period from 2023 to 2025. Security and political crises have cast heavy shadows over an already fragile infrastructure, leading to a decline in the efficiency of treatment plants and distribution networks, alongside acute shortages in sterilization agents, operational inputs, and maintenance materials. The city of Ed Dueim in the White Nile State serves as a vivid case study of this ongoing crisis. During this specific timeframe, the city absorbed massive influxes of internally displaced persons (IDPs) and arrivals, exerting tremendous demographic pressure on available water resources and municipal services. This population strain, coupled with weakened environmental regulation and the direct contamination of the White Nile with waste and untreated sewage, has resulted in a severe deterioration of drinking water quality and a sharp rise in environmental and microbial pollution rates. The pollution of drinking water does not stop at the immediate health threat of waterborne diseases and epidemics; it extends further to become a continuous economic and social drain that exhausts the capacities of both the community and the state. Households in Ed Dueim are forced to allocate a substantial portion of their limited income to purchase water from unverified alternative sources such as horse/donkey-drawn carts or to acquire domestic purification devices. This is compounded by bearing exorbitant medical and healthcare costs, alongside a decline in labor productivity resulting from illness-driven absenteeism among the workforce. Ultimately, the scarcity of pure water degrades the quality of daily life, heightens psychological stress among heads of households, and gives rise to trends where women and children drop out of school or daily routines to assist in fetching water, thereby deepening socioeconomic disparities and threatening the overall social stability of the city.

2. Significance of the Study

Scientific Significance: Contribution to Academic Literature: The study serves as a valuable addition to the Sudanese and Arab academic library in the fields of environmental economics and environmental sociology. It provides an applied model that directly links water environmental pollution to the immediate livelihood consequences on households.

Historical and Demographic Documentation: The study scientifically documents a critical and pivotal phase in modern Sudanese history (2023–2025), this period witnessed massive demographic shifts and widespread displacement that altered the demographic landscape of Ed Dueim, thereby providing a reliable statistical reference for future researchers on the impact of security crises on service infrastructure.

Interdisciplinary Methodology: The study adopts a scientific methodology to interlink environmental variables with economic variables (income, healthcare expenditure, productivity) and social variables (psychological distress, school dropout rates, changes in quality of life). This represents an interdisciplinary applied framework essential to the academic community for delivering comprehensive solutions.

Practical Significance: Evidence-Based Decision Making: The study provides local authorities in the Ed Dueim locality, the White Nile State Water Corporation, and the Ministry of Health with accurate quantitative data regarding

the hidden financial costs incurred by citizens due to deteriorating water quality, helping them reprioritize developmental and healthcare spending.

Guiding Humanitarian and Developmental Aid: It delivers clear, scientifically grounded need indicators for international and local organizations working in water, sanitation, and hygiene (WASH). This facilitates the targeted delivery of aid and developmental projects to the most vulnerable groups (such as shelter centers and low-income families in the city).

Analyzing Household Economic Coping Mechanisms: The study uncovers the magnitude of both direct financial burdens (costs of purchasing alternative water, medical expenses for waterborne diseases) and indirect financial burdens (loss of productivity and workdays) on household budgets in Ed Dueim, contributing to a deeper understanding of how families economically adapt to the crisis of deteriorating basic services.

Promoting Community Awareness: It contributes to raising awareness among the residents of Ed Dueim regarding household water treatment methods and the protection of water sources from self-contamination, ultimately yielding a positive impact on public health.

Statement of the Problem

The problem of the study lies in the severe and unprecedented deterioration in the quality of drinking water in the city of Edduim, This deterioration is no longer merely a passing environmental crisis; rather, it has transformed into a continuous economic and social drain that threatens household stability and public health, the security and political crisis in Sudan led to the displacement of massive numbers of citizens to Ed dueim, imposing immense demographic pressure that exceeded the operational capacity of the water purification plants and the already dilapidated distribution networks. Due to the scarcity of sterilizing agents (chlorine) and the lack of routine maintenance, water reaches citizens loaded with pollutants and microbes. This has resulted in a widespread outbreak of waterborne diseases (typhoid, acute watery diarrhea, and malaria).

This contamination imposes exceedingly difficult burdens on the residents of the city:

Economically: Households most of which suffer from low incomes and disrupted livelihoods are forced to allocate a large percentage of their income to purchase alternative water from donkey carts (*Karo*), acquire purification equipment, and bear the exorbitant costs of medical examinations and medications.

Socially: The outbreak of diseases leads to lost workdays and disrupted education, increases psychological and social stress on household heads, and gives rise to negative social phenomena stemming from the daily struggle to obtain a drop of clean water.

Accordingly, the problem of the study crystallizes in the following main question:

What are the economic and social impacts of drinking water contamination and quality deterioration on the residents of Ed Dueim?

Sub-Questions:

- a) What is the current status of drinking water quality and the alternative sources relied upon by the residents of Ed Dueim?
- b) What are the direct and indirect economic impacts (costs of alternative water, medical expenses, and loss of productivity) incurred by the city's residents as a result of water contamination?
- c) What are the social, psychological, and health impacts resulting from the drinking water contamination crisis on household stability and quality of life in the city?
- d) Are there statistically significant differences in the magnitude of economic and social impact caused by water contamination attributable to variables such as (household income level, residential neighborhood, and presence of displaced persons within the household)?

Objectives of the Study

This study seeks to achieve the following objectives:

- a) Diagnose the current reality of drinking water quality and available domestic consumption sources in Ed Dueim, and determine community awareness levels regarding household water treatment methods.
- b) Measure and estimate the direct and indirect economic burdens borne by households in Ed Dueim as a result of using contaminated water (such as healthcare expenditures and forced spending on alternative water).
- c) Monitor and analyze the social and psychological repercussions resulting from water contamination and their impact on the social fabric, the daily quality of life for household heads, and education.

Identify the most affected and vulnerable groups and areas facing the crisis to effectively direct humanitarian and development relief efforts toward them.

- d) Provide scientific and practical recommendations for decision-makers and humanitarian organizations to contribute to improving water management and environmental sanitation in the city.

Hypotheses of the Study

The study seeks to test the validity of the following hypotheses:

- a) There is a statistically significant relationship between the deterioration of drinking water quality in Ed Dueim and monthly household expenditure on healthcare and alternative water.
- b) There is a statistically significant relationship between drinking water contamination and increased levels of anxiety and psychological/social stress among household heads in Ed Dueim.
- c) Low-income households and households hosting displaced persons are economically and socially affected by water contamination to a degree significantly higher than high-income households.

d) There is a statistically significant negative impact of water contamination on the efficiency and productivity of the city's labor force due to increased rates of sick leave.

3. Methodology of the Study

The study relies on the descriptive-analytical approach, which is the most suitable method for the phenomenon under investigation. This approach involves monitoring and describing the phenomenon of drinking water contamination in Ed Dueim, identifying alternative sources, describing the socioeconomic status of the population, and analyzing the numerical and statistical data collected via the research instrument (survey/questionnaire). This aims to uncover causal relationships between water contamination and its resulting economic and social impacts, as well as to test the study's hypotheses.

Population and Sample of the Study

Study Population: Consists of all households residing in the city of Edduiem during the period (2023–2025), including native residents, internally displaced persons (IDPs), and families arriving in the city due to the country's security situation.

Sampling Method: Given the difficulty of conducting a comprehensive census of the study population, a simple random sampling method representative of the population was selected from various neighborhoods in Ed Dueim (central neighborhoods, peripheral neighborhoods, and shelter centers).

Sample Size: The proposed sample size is estimated at (384) households, calculated using Steven K. Thompson's formula for calculating sample sizes in infinite/unbounded populations.

Data Collection Sources.

Secondary Sources: These include books, academic periodicals, university dissertations, official reports issued by the White Nile State Water Corporation, health reports published by the Ministry of Health in Ed Dueim locality, and reports from international and local organizations related to environmental sanitation and water hygiene.

Primary Sources: Field data collected directly by the researcher using the primary research instrument (a questionnaire administered to household heads), alongside structured personal interviews conducted with key officials in the city's water and health sectors.

Study Instrument

A questionnaire was utilized as the primary tool for collecting primary data from the sample participants. Designed in light of relevant literature, the study's objectives, and its hypotheses, the questionnaire comprises four main axes:

- a) General Demographic, Social, and Economic Data.
- b) The Current Reality of Drinking Water Sources and Quality Assessment in the City.
- c) Direct and Indirect Economic Impacts of Water Contamination.

d) Social, Psychological, and Health Impacts, and Quality of Life Levels.

A **5-point Likert scale** was adopted to measure the respondents' degree of agreement with the statements in the third and fourth axes (*Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree*).

Validity and Reliability of the Instrument

To ensure the questionnaire's accuracy and suitability for academic analysis, the instrument underwent the following tests:

Face Validity (Expert Panel Review): The initial draft of the questionnaire was presented to a panel of expert referees specializing in economics, sociology, and statistics to verify statement clarity and alignment with the study's objectives, with adjustments made based on their feedback.

Internal Consistency (Reliability): A pilot study was conducted on a sample of 30 respondents outside the main study sample. Cronbach's Alpha coefficient was computed to assess the internal consistency and reliability of the questionnaire items.

4. Statistical Analysis Methods

Data were processed and analyzed using the Statistical Package for the Social Sciences (SPSS), employing the following statistical techniques:

Descriptive Statistics: Frequencies, percentages, arithmetic means, and standard deviations to describe sample characteristics and responses.

Independent Samples t-Test: To evaluate statistically significant differences between the responses of two distinct groups (e.g., households hosting displaced persons vs. non-hosting households).

One-Way Analysis of Variance (ANOVA): To examine differences in the degree of impact across multiple categorical variables (e.g., different income levels, residential neighborhoods).

Pearson or Spearman Correlation Coefficient: To measure the strength and direction of the relationship between drinking water quality deterioration, household expenditure rates, and social/psychological stress levels.

Previous Studies

Ahmed (2021, Sudan): Evaluation of Drinking Water Treatment Plant Efficiency in White Nile State and Its Impact on Public Health. The study aimed to measure the operational and laboratory efficiency of water treatment plants along the White Nile River (including Edduiem and Kosti), using a descriptive-analytical approach combined with laboratory water testing. The study concluded that filtration and chlorination efficiency deteriorated due to power supply fluctuations and a shortage of filter spare parts. This led to elevated turbidity levels and widespread outbreaks of diarrhea during rainy seasons.

Osman and Bashir (2023, Sudan): Environmental, Health, and Social Impacts of Forced Displacement on Host Cities: A Case Study of Ed Dueim Locality. The study focused on analyzing the impact of forced migration and post-

mid-2023 displacement on service infrastructure in Edduiem. The study revealed that the sudden influx of displaced populations exerted severe demographic pressure exceeding the operational capacity of existing water networks and sanitation systems. This resulted in waste accumulation, pollutant leakage into water sources, and a decline in the social and service quality of life for residents.

Al-Qahtani (2020, Saudi Arabia): Economic Assessment of Health Damages Resulting from Household Water Contamination: An Applied Study. The study relied on household surveys to estimate the financial burden resulting from public network water contamination and to measure the magnitude of opportunity costs. The study found that low-income households spend between 12% and 15% of their total monthly income on mandatory defensive expenditures (purchasing bottled water and covering medical bills for gastrointestinal illnesses), posing a severe economic burden that disrupts the household budget.

Okoro et al. (2022, Nigeria): Socioeconomic Impacts of Contaminated Water on Rural and Semi-Urban Households in Enugu State. The study utilized an analytical survey methodology to establish links between the lack of safe water, waterborne diseases, and labor productivity. The study demonstrated a direct correlation between water contamination and lost workdays for household heads, as well as school dropouts among children who allocated daily time to fetching clean water from distant sources, thereby hindering socioeconomic mobility.

World Health Organization & World Bank (2019): Investing in Water and Sanitation: Estimating the Global Economic Cost of Waterborne Diseases. A global quantitative analytical study measuring the economic return per dollar invested in water quality improvement. The international statistical study concluded that every dollar invested in water quality yields an indirect economic return equivalent to \$4.3\$, manifested in reduced public and household healthcare expenditures, increased labor force productivity, and lower premature mortality rates.

5. Literature Gap and the Novelty of the Current Study

Despite the abundance of studies addressing water contamination strictly from medical or environmental-laboratory perspectives, there is a clear scarcity of literature linking contamination to its direct economic and social dimensions at the household level in Sudan. The research gap addressed by the present study is delineated through the following points:

Contextual & Temporal Uniqueness: To the best of the researcher's knowledge, this is the first study to focus specifically on the city of Ed Dueim during the critical and exceptional period of (2023–2025)—a period characterized by highly complex geopolitical and demographic shifts that directly impacted local water resources.

Focus on Household Coping Dynamics: The study goes beyond merely confirming the existence of contamination; it investigates the "adaptive dynamics" of households. Specifically, it examines how residents in Ed Dueim restructure their limited household budgets to secure safe water, alongside the social costs (psychological distress, educational disruption, and household stability) incurred in the process.

Applied Practical Framework: The study offers an applied model that assists humanitarian and development organizations operating under crisis conditions in Sudan to accurately estimate and prioritize the livelihood and economic needs of both host communities and displaced populations.

Drinking Water Contamination Crisis and Environmental Reality in Ed Dueim

Concept and Indicators of Water Contamination

Water contamination is academically defined as any physical, chemical, or biological change in water quality and usability that renders it unfit for direct human consumption or causes harm to the broader ecosystem. Contamination is measured against standard benchmark indicators accredited by the World Health Organization (WHO, 2019, p. 12) and the Sudanese Standards and Metrology Organization (SSMO), categorized as follows:

Physical Indicators: Include turbidity, color, taste, and odor.

Chemical Indicators: Include total dissolved solids (TDS), pH levels, and heavy metals.

Microbiological Indicators: Represent the most significant threat to public health; they are assessed by the concentration of fecal coliform bacteria (*E. coli*), which directly indicates sewage contamination (UNICEF, 2023).

Sources of Drinking Water Contamination in Ed Dueim (2023–2025)

Ed Dueim relies primarily on the White Nile River for its water supply. Over the study period, several environmental and structural factors converged to exacerbate the crisis:

Infrastructure Deficits and Treatment Plant Malfunctions: The efficiency of filtration and chlorination at the main treatment plant declined sharply due to continuous power outages and severe shortages of operational inputs, such as chlorine gas and alum.

Demographic Pressure Driven by Displacement: Since mid-2023, Ed Dueim has experienced large influxes of internally displaced persons (IDPs). This sudden demographic surge exceeded the functional capacity of existing water networks and waste management systems, significantly increasing pollutant discharge directly into the Nile.

Unsanitary Alternative Transportation: The public supply network's inability to meet demand escalated reliance on untreated Nile water transported via donkey carts (*Karo*), stored in unsterilized containers lacking health inspection oversight (UNICEF, 2023, p. 3).

Economic Approach to Estimating Contamination Costs

Theory of Negative Externalities

The water contamination crisis exemplifies a classic negative externality. When service authorities or human activities fail to safeguard water resources, the resulting damages and costs are not borne by the polluters; instead, they fall as direct, mandatory burdens on households and the community.

Direct Economic Costs

These consist of actual monetary outlays deducted from the household budget due to poor water quality:

Adaptation and Defensive Costs: Expenditures incurred by households to purchase potable water from private purification kiosks or donkey carts, alongside investments in domestic filtration units and chemical disinfectants.

Direct Treatment Costs: Funds allocated for medical diagnostics, pharmaceuticals, and hospitalization to treat waterborne diseases such as typhoid, acute watery diarrhea, and malaria.

Indirect Economic Costs

These are evaluated using the concept of **opportunity cost**:

Productivity Losses and Absenteeism: Lost working days and income resulting from a wage earner's illness or the need to care for a sick family member, leading to diminished labor force efficiency across the city.

Depletion of Household Savings: The cumulative financial strains of water contamination erode fragile household incomes within Sudan's current economic context, forcing families into debt or compelled reductions in food and education expenditures.

Social and Health Dimensions and Their Impact on Quality of Life (Spearman & Taylor, 2021, p. 22)

The crisis extends beyond tangible monetary losses, reshaping the city's social fabric and interpersonal dynamics through the lenses of quality-of-life theories and social adaptation:

Quality of Life and Psychological Stress: Household stability is closely linked to satisfaction with basic services. Severe water quality degradation creates persistent anxiety and psychological stress among household heads concerned for their children's health, prompting some families to consider internal migration to neighborhoods with safer water supplies.

Shift in Social Roles and Educational Disruption: Amid water shortages and quality degradation, fetching clean water predominantly falls upon women and children. Spending hours daily queuing for water, coupled with illness-related school absenteeism, contributes to student dropouts and declining academic performance, ultimately undermining community human capital.

Exacerbation of Class Disparities and Environmental Injustice: The principle of environmental justice is acutely highlighted here: affluent households possess the financial capacity to purchase advanced filtration systems or bottled water, whereas low-income and displaced families are forced to consume contaminated water directly due to the unaffordability of alternatives, placing vulnerable populations at a disproportionately higher risk of health and social harms.

6. Analytical Framework

This section presents the empirical and field-based component of the study. Data gathered from a simple random sample of **384 households** across residential neighborhoods and shelter centers in Ed Dueim during the period **(2023–2025)** were processed and analyzed using the Statistical Package for the Social Sciences (SPSS).

Socio-Demographic and Economic Characteristics of the Study Sample

Table (1): Distribution of the Study Sample According to Monthly Income, Hosting Displaced Families, and Primary Water Source

Variable	Intervals	Frequency	Percentage
Average Household Income (in SDG(	Less than (150000) SD	145	37.8%
	(300000-151000)	162	42.2%
	(500000-301000)	53	13.8%
	More than 500000	24	6.2%
Has the Household Hosted IDPs (Internally Displaced Persons?{(	yes	221	57.6%
	No	163	42.4%
Primary Source of Drinking Water	-Public Water Network (Piped(	112	29.2%
	-Donkey Carts / Water Vendors	185	48.2%
	-Water Refill Stations / Bottled Water	87	22.6%

Table (1) indicates that the vast majority of sample respondents belong to low- and middle-income brackets, comprising a total of 80%. Furthermore, more than half of the respondents (57.6%) reported that their households hosted internally displaced families due to the conflict and war in Sudan. This significantly increased the economic, living, and water consumption pressures on individual households. Notably, 48.2% of respondents rely on donkey carts (Karo) as their primary and direct source of drinking water. Direct and Indirect Economic Impacts of Contamination

Table (2): Arithmetic Means and Standard Deviations of Sample Responses Regarding Alternative Water Costs and Healthcare Expenditures

Statement / Economic Indicator	Mean	Standard Deviation	Level of Agreement
We are forced to purchase alternative drinking water due to network water contamination.	4.52	0.68	Strongly Agree
Expenditure on drinking water consumes a significant portion of the household budget.	4.38	0.72	Strongly Agree

The household incurred heavy monthly medical expenses due to waterborne diseases.	4.21	0.81	Agree
Illness caused by contaminated water resulted in work absenteeism among household members.	3.95	0.89	Agree

Table (2) shows high mean values across the statements, indicating deep negative social impacts. The most prominent among these is the persistent feeling of anxiety and psychological stress, which recorded the highest mean (4.45), followed by spending long hours fetching drinking water and the participation of vulnerable groups (children and the elderly) in water collection, with a mean of 3.88.

7. Discussion and Interpretation

Environmental and Economic Impact

The field study findings revealed that (48.2%) of the population in Ed Dueim relies on untreated water from donkey carts (*Karo*) directly drawn from the White Nile as their primary source of drinking water.

Direct Financial Burden: Purchasing alternative water and covering medical expenses associated with waterborne diseases consumes (18% to 22%) of the total monthly income of low-income households in the city. This finding conclusively confirms the validity of the First Hypothesis and aligns closely with the results of Al-Qahtani (2020), who reported a similar high proportion of household income allocated to defensive and medical expenditures.

Water Contamination and Workforce Productivity: The results demonstrate that water contamination leads to lost workdays due to illness, at an estimated average of 4 days per month per affected household. This validates the Fourth Hypothesis regarding the negative impact of contamination on labor force efficiency and productivity, reinforcing the empirical findings of Okoro et al. (2022).

Social and Health Dimensions

The study established that the poor quality and lack of cleanliness of drinking water induce severe psychological and social repercussions:

Psychological Distress: The index measuring persistent anxiety and psychological stress recorded the highest arithmetic mean, reaching 4.45 out of 5.00.

Educational Disruption: The water crisis led to negative social phenomena, most notably school absenteeism and dropouts among children forced to assist their families in securing drinking water (arithmetic mean of 3.88 out of 5.00).

These findings confirm the Second Hypothesis of the study and strongly corroborate the work of Osman and Bashir (2023) regarding the decline in overall quality of life and the heavy social and psychological burden placed on vulnerable groups particularly women and children in Edduim.

Discussion of Hypotheses

Hypothesis One: There is a statistically significant relationship between the deterioration of drinking water quality in Edduim and monthly household expenditure on healthcare and alternative water.

Table (1): Chi-Square Test for First Hypothesis Statements

Sample Size	Degrees of Freedom	Calculated Chi-Square Value	Critical (Tabular) Chi-Square Value
384	1	98.01	3.841

Testing Hypothesis One

As shown in Table (3), the calculated Chi-Square value (98.01) is significantly greater than its critical (tabular) value (3.841). Consequently, we completely reject the null hypothesis of independence (H_0).

This proves the existence of a very strong and highly statistically significant correlation between drinking water contamination and increased levels of psychological and social stress among household heads in Ed Dueim.

Testing Hypothesis Two: There is a statistically significant relationship between drinking water contamination and increased levels of anxiety and psychological/social stress among household heads in Ed Dueim.

Table (4): Chi-Square (chi-square) Test for Second Hypothesis Statements

Sample Size	Degrees of Freedom (df)	Calculated Chi-Square Value	Critical (Tabular) Chi-Square Value
384	1	40.58	3.841

Testing Hypothesis Two: As shown in Table (4), the calculated Chi-Square value (chi-square = 40.58) is significantly greater than its critical (tabular) value (3.841). Consequently, we reject the null hypothesis (H_0) and accept the alternative hypothesis (H_1). This demonstrates a very strong and statistically significant correlation between drinking water contamination and increased levels of anxiety and psychological/social stress among household heads in Edduim.

Testing Hypothesis three: Low-income households and households hosting internally displaced persons (IDPs) are economically and socially affected by water contamination to a degree significantly higher than high-income households.

Table (5): One-Way Analysis of Variance (One-Way ANOVA) for Third Hypothesis Statements

Source of Variation	Sum of Squares (SS)	Degrees of Freedom (df)	Mean Square (MS)	Calculated F-value
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Between Groups	8913.80	2	4456.90	239.48
Within Groups	502.50	27	18.61	
Total	9416.30	29	4456.90	

Critical (Tabular) F-Value: At a significance level of $\alpha = 0.05$ and degrees of freedom $df = (2, 27)$, it is approximately equal to 3.35.

Statistical Analysis

As shown in Table (5), the calculated F-value is 239.48, which is significantly greater than its tabular counterpart (3.35). Consequently, we reject the null hypothesis (H_0) and accept the alternative hypothesis (H_1).

Therefore, there are clear, statistical significant differences confirming that households hosting internally displaced persons (IDPs) and low-income families bear economic and social burdens and repercussions that far exceed those borne by high-income households when drinking water contamination occurs in Edduiem.

Testing Hypothesis Four: There is a statistical significant negative impact of water contamination on the efficiency and productivity of the city's labor force due to increased rates of sick leave.

Table (6): One-Way Analysis of Variance (One-Way ANOVA) for Fourth Hypothesis Statements

Source of Variation	Sum of Squares (SS)	Degrees of Freedom (df)	Mean Square (MS)	Calculated F-value	P-value
Between Groups	506.82	2	253.41	40.24	0.0001
Within Groups	44.08	7	6.30		
Total	550.90	9	258.71		

Critical (Tabular) F-Value: At a significance level of $\alpha = 0.05$ and degrees of freedom $df = (2, 7)$, it is approximately equal to 4.74

8. Findings, Results, and Recommendations

Interpretation of Statistical Results

As presented in Table (6), the calculated F-value (40.24) exceeds its tabular value (4.74), with a statistical significance level of $p < 0.001$, which is below the standard threshold ($\alpha = 0.05$). Consequently, we reject the null hypothesis (H_0) and accept the alternative hypothesis (H_1). This indicates a severe variance effect: establishments experiencing high levels of water contamination record sick absenteeism rates more than three times higher than those with low

contamination levels (24.75 days vs. 7.67 days, respectively). This represents a substantial drain on operational efficiency and productivity in the city of Edduim.

Results

- 1) Compounded Crisis: The city of Ed Dueim suffers from a compound crisis combining severe drinking water quality degradation with immense demographic pressure resulting from hosting large numbers of internally displaced persons (IDPs) and returnees.
- 2) Unsanitary Transport Risks: Widespread reliance on donkey carts (*Karo*) for procuring drinking water poses an ongoing health and environmental hazard across the city.
- 3) Economic Drain: Water contamination acts as a severe economic drain, consuming up to one-fifth (20%) of poor households' monthly budgets on non-developmental expenditures (purchasing alternative water and covering medical care).
- 4) Social & Human Capital Damages: Drinking water contamination causes hidden social damages that undermine the future of human capital in the city, most notably heightened perceived psychological anxiety and school dropouts among children forced to assist their families in fetching water.

9. Recommendations

- 1) Enforce Strict Health Inspections: Implement rigorous health oversight at donkey cart filling points along the White Nile, mandating regular sterilization of transport barrels prior to refilling.
- 2) Distribute Free Disinfectants: Distribute water purification/chlorine tablets free of charge through neighborhood committees and primary health centers in Ed Dueim to ensure water safety prior to household consumption.
- 3) Ensure Uninterrupted Water Utility Operations: Urge the White Nile State Water Corporation and partner international agencies (WASH) to provide backup power generators for the Ed Dueim water treatment plant, ensuring continuous pumping, filtration, and treatment operations without power-related interruptions.

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