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Original Article

"Municipality-Specific Determinants of Chronic Kidney Disease in Southern Libya: Comparative Analysis of Clinical, Behavioral, and Environmental Risk Factors"

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Abstract

Background: Chronic Kidney Disease (CKD) poses a major public health challenge worldwide, with Diabetes Mellitus (DM) and Hypertension (HTN) being the leading drivers of progression to End-Stage Renal Disease (ESRD). In Southern Libya, preliminary reports from Tasawa, Al-Qatrun, Traghen, and Obari indicate an alarming rise in ESRD cases requiring dialysis. **Objective:** This study aims to compare clinical, behavioral, and environmental determinants of CKD across four Southern Libyan municipalities, identifying localized high-risk patterns to inform targeted prevention strategies.**Methods:** An integrated risk-assessment framework was applied, evaluating clinical factors (glycemic and blood pressure control), behavioral factors (obesity, chronic analgesic use, herbal remedies), and environmental exposures (groundwater quality, Total Dissolved Solids [TDS]). Comparative analyses were conducted to detect inter-municipality variations in CKD risk profiles**.**
Results: Preliminary findings suggest heterogeneous distribution of risk factors, with specific municipalities exhibiting higher prevalence of uncontrolled DM, HTN, obesity, and exposure to poor-quality drinking water.
Conclusion: Municipality-specific risk profiling provides essential evidence for targeted interventions and early CKD prevention strategies, reducing progression to ESRD in resource-limited settings**.**

Keywords: Chronic Kidney Disease, Diabetes Mellitus, Hypertension, Environmental Risk, Southern Libya, Targeted Prevention

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INTRODUCTION:

Chronic Kidney Disease (CKD) has become a significant public health concern worldwide, contributing substantially to illness and mortality and placing heavy demands on healthcare systems and economies. highlighting the urgent need for effective strategies to prevent and manage the disease [1]. The progression from early CKD to End-Stage Renal Disease (ESRD) is strongly influenced by chronic conditions such as Diabetes Mellitus (DM) and Hypertension (HTN), which account for most cases of renal failure globally [2]. Poor blood sugar control, often reflected in high HbA1c levels, accelerates kidney damage through mechanisms like glomerular hyperfiltration, accumulation of harmful glycation products, and oxidative stress. Similarly, sustained high blood pressure can lead to structural damage in the kidneys, including glomerulosclerosis and fibrosis of the renal tubules [3].

In the Middle East and North Africa (MENA) region, lifestyle changes such as increasing obesity rates, metabolic syndrome, and reduced physical activity have contributed to a growing risk of CKD [4]. In Libya, ongoing political and economic challenges have weakened healthcare capacity, limiting effective management of chronic diseases. Certain southern municipalities, including Tasawa, Al-Qatrun, and Traghen, have experienced a noticeable rise in new ESRD cases requiring dialysis, suggesting that CKD risk is not uniformly distributed and may cluster in specific areas due to a mix of clinical, behavioral, and environmental factors [5].

Lifestyle and behavioral factors further influence kidney health. Obesity increases insulin resistance, inflammation, and renal workload, accelerating kidney injury. Long-term use of non-steroidal anti-inflammatory drugs (NSAIDs) can damage renal tissue, while some unregulated herbal remedies may contain compounds harmful to the kidneys, particularly in people with metabolic vulnerabilities [6]. Environmental exposures also play a role; for example, consuming groundwater with high levels of dissolved solids may contribute to kidney stones, tubular damage, and faster CKD progression in susceptible individuals [7.8].

A comprehensive understanding of how these clinical, behavioral, and environmental factors interact in specific municipalities is essential for public health planning. Traditional approaches often overlook geographical variations, which can result in interventions that are too generalized. By examining the prevalence and distribution of CKD determinants in Tasawa, Al-Qatrun, Traghen, and Obari, this study seeks to provide evidence that can guide targeted interventions, optimize resource allocation, and reduce progression to ESRD in settings with limited resources.[9]

MATERIAL AND METHOD:

1 Study Design and Setting

This study utilized a comparative, multi-component, cross-sectional approach [1], conducted as part of the National Project for Investigating the Causes of Increased Renal Failure in Southern Libya. Data were collected during [insert period] across four municipalities—Tasawa, Al-Qatrun, Traghen, and Obari—which were identified as high-risk areas for emerging ESRD cases. The chosen design allowed for a comprehensive assessment of clinical, behavioral, and environmental determinants of CKD simultaneously across these locations.

1.2 Study Population and Sampling

The study included 1,157 participants, recruited from hospital outpatients and attendees at other healthcare facilities, who were randomly selected to ensure representative sampling across the targeted municipalities: Tasawa (n = 379), Al-Qatrun (n = 297), Traghen (n = 352), and Obari (n = 129). Participants were drawn from chronic disease clinics and general hospital outpatient services.

Ethical clearance was obtained from [insert ethics committee], and written informed consent was collected from all participants before enrollment. The sampling strategy was designed to minimize selection bias and ensure proportional representation from each municipality.

1.2 Data Collection Procedures

1.2.1 Clinical and Laboratory Assessment

Participants considered at high risk underwent detailed clinical evaluations at local health centers. Laboratory tests included fasting blood glucose, HbA1c, serum urea, and creatinine levels [2]. Proteinuria was assessed using urine dipstick tests. Additionally, medical records from dialysis centers, particularly in Obari, were reviewed to determine the underlying causes of ESRD**.**

1.2.2 Community-Based Survey

Structured questionnaires were administered to gather data on sociodemographic characteristics, medical history, obesity, and behavioral risk factors, including chronic use of NSAIDs and intake of unverified herbal products [3].

1.2.3 Environmental Water Quality Assessment

Water samples were collected from community wells and reservoirs. Total Dissolved Solids (TDS) were measured using calibrated meters and compared with WHO-recommended limits (≤1000 mg/L) [4]. Additional analyses included screening for heavy metals (Pb, Cd, Fe) and microbiological contaminants, such as *E. coli*. Patterns of water source utilization and daily water consumption were documented.

1.4 Statistical Analysis

Data were analyzed using SPSS version 21. Descriptive statistics summarized participant characteristics and CKD risk factors. Differences in categorical variables between municipalities were assessed using Chi-square tests, with significance set at $p < 0.05$.

RESULT:

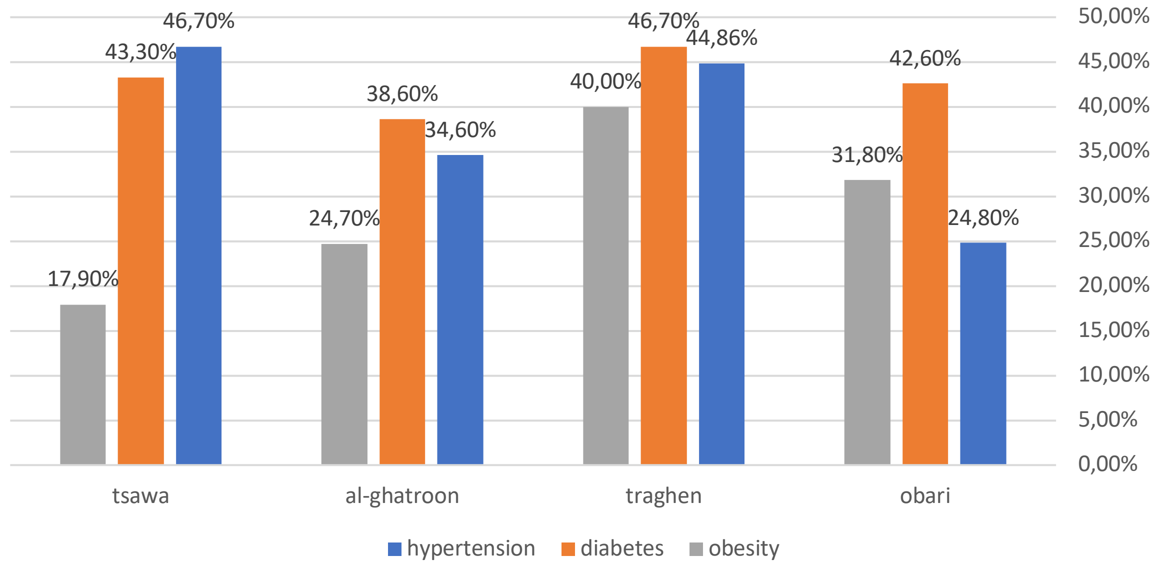
Distribution of Metabolic and Behavioral Risk Factors

The prevalence of metabolic disorders varied markedly across the four municipalities. Traghen showed the highest rates of diabetes (46.7%) and hypertension (44.9%), highlighting a municipality with significant cardiometabolic stress. Tsaoua also demonstrated high hypertension levels (46.7%), while Obari and Al-Ghatroun showed comparatively lower but still substantial prevalence.

Obesity was most common in Traghen (40%), followed by Obari (31.8%), suggesting lifestyle and nutritional factors contribute to CKD risk.

Table 1. Prevalence of Metabolic and Behavioral Risk Factors Across Municipalities

Variable	Tasawa	Al-Qatrun	Traghen	Obari	p-value
Diabetes	164	115	164	55	**0.252** (Not significant)
Hypertension	177	103	158	32	**<0.001** (Highly significant)
Obesity	68	74	141	41	**<0.0001** (Highly significant)

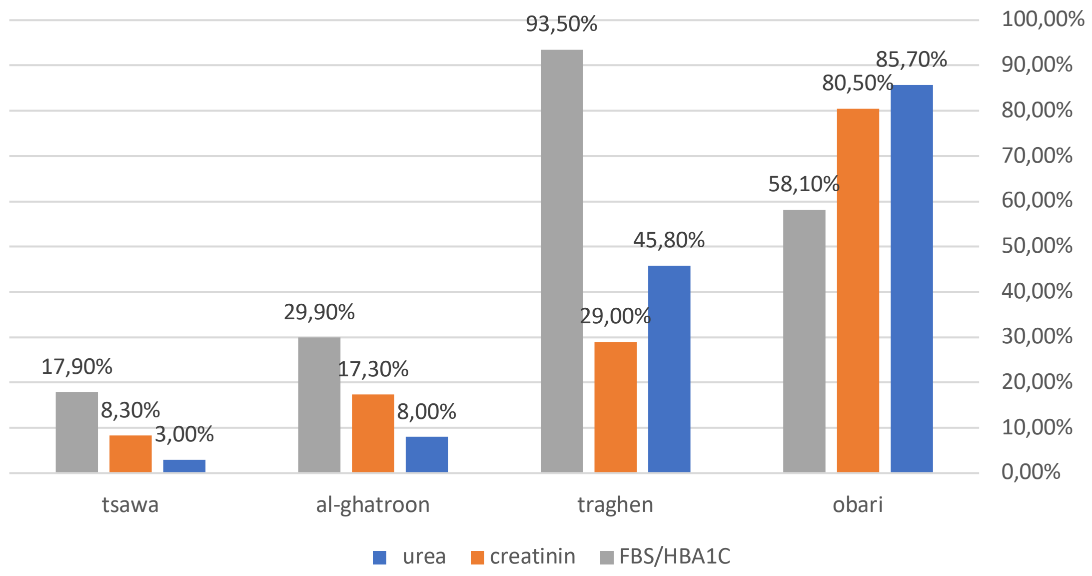


Metabolic Control and Renal Function Indicators

Renal impairment indicators showed extreme geographic variability. Obari had the highest proportions of abnormal renal markers: Urea 85.7%, Creatinine 80.5%, indicating advanced kidney injury in a large segment of the population. In Traghen, displayed severe metabolic dysregulation, with 93.5% having elevated HbA1c, suggesting long-standing uncontrolled diabetes—an established driver of nephropathy. Tsaoua showed relatively better renal markers but still demonstrated 52% elevated HbA1c, indicating chronic poor control of diabetes. Al-Ghatroun had the lowest abnormal indicators, reflecting better disease management or lower environmental exposures

Table 2. Laboratory Markers of Disease Control and Renal Function

Variable	Tasawa	Al Qatrun	Traghen	Obari	p-value
High Urea	11	24	161	111	**<0.0001** (Highly significant)
High Creatinine	31	51	102	104	**<0.0001** (Highly significant)
High HbA1c	197	89	329	75	**<0.0001** (Highly significant)



Environmental and Lifestyle Factors

Environmental profiles revealed substantial heterogeneity. **Traghen** reported the **highest TDS level (1172 mg/L)**—above WHO palatability and acceptability thresholds—suggesting possible chemical contaminants that could aggravate renal injury. **Obari** had the lowest hydration levels (17.2%), consistent with dehydration-linked tubular stress. Reliance on untreated well water was highest in **Tsaoua (78.9%)** and **Obari (63.3%)**, increasing exposure to unmonitored chemical and microbial contaminants. Overall, the results indicate that **Traghen and Obari are the highest-risk areas**, each for different but overlapping reasons: Traghen due to metabolic and environmental factors, and Obari due to advanced renal impairment and poor hydration patterns.

Table 3. Environmental Exposure and Hydration Profiles.

Variable	Tasawa	Al-Qatrun	Traghen	Obari	p-value
Adequate Hydration (>2 L/day)	167	137	125	22	<0.0001
Use of Local Well Water	299	44	116	82	<0.0001

Table 4. Water Analysis Results Comparison Table

City	Microbiological Contamination	Total Dissolved Solids (TDS)	Heavy Metals
Tsaoua (Wadi Utba)	4 wells were found to have bacterial contamination, exposing the population to gastrointestinal diseases.	High salinity was found in a number of wells, which contributes to urinary tract stones.	Analysis was conducted, but detailed results are not available in the text excerpts.
Traghen	Analysis was conducted.	Very high levels in some wells (e.g., 1172 ppm), and low, safe levels in desalinated water (e.g., 79 ppm).	Analysis was conducted.
Obari	Analysis was conducted-	Analysis was conducted.	Results showed the absence of Lead (Pb), Cadmium (Cd), and Iron (Fe) in the city's water-2.pptx].
Al-Ghatroun	Analysis was conducted.	TDS analysis was conducted.	Heavy metals analysis was conducted.

This table compares the laboratory analysis results conducted by the research team on drinking water samples collected from each city, focusing on the three main indicators: Microbiological Contamination, Total Dissolved Solids (TDS), and Heavy Metals

DISCUSSION:

The geographic differences observed in this study demonstrate that CKD risk in Southern Libya is shaped by uneven distributions of metabolic, behavioral, and environmental stressors, confirming patterns seen in earlier Libyan and international reports. Our finding that Traghen has the poorest glycemic control (HbA1c 93.5%) and a high diabetes prevalence mirrors previous Libyan analyses that reported significant variability in diabetes control between regions, often linked to disparities in access to primary care, medication availability, and follow-up systems [11.10]. Similar patterns were reported by Tabatabaei Malazy et al. (2022), who described substantial regional variation in CKD risk across North Africa driven by inconsistent chronic disease management.

The extremely elevated renal markers observed in Obari align with earlier reports documenting rising ESRD incidence in underserved Libyan municipalities[12.13]. These high numbers suggest delayed diagnosis and poor continuity of chronic disease management—factors widely recognized as accelerators of CKD progression in resource-limited settings [14].

Environmental results further support a multifactorial risk pattern. The TDS level of 1172 mg/L in Traghen exceeds WHO thresholds and resembles environmental characteristics of CKD hotspots in Sri Lanka, where elevated dissolved solids and trace elements in groundwater were identified in communities with high CKDu burden [15.16]. Although causality cannot be assumed, the similarities indicate that local water chemistry could be a contributing factor requiring further investigation.

Comparable patterns of environmental-heat-dehydration interactions were reported in Central America and South Asia, where chronic dehydration, agricultural exposures, and water contaminants contributed to CKD clusters among working-age adults [17.18]. Behavioral risk factors in our population further compound this risk. Chronic NSAID use and unregulated herbal remedy consumption—both common in the study area—have well-documented nephrotoxic effects [19]. demonstrated that long-term analgesic use contributes to tubulointerstitial injury [20].reported similar nephrotoxic effects of certain herbal compounds, particularly in individuals with pre-existing metabolic disease. The combination of uncontrolled diabetes, nephrotoxic medication practices, dehydration, and potential environmental contaminants in Traghen and Obari aligns with global models of multifactorial CKD acceleration seen in tropical agricultural communities[21.22].

The dramatic differences between municipalities—despite geographic proximity—strongly suggest localized health system weaknesses, variable water quality, and differences in behavioral practices. WHO's drinking water quality guidance emphasizes that very high TDS often coexists with other dissolved contaminants, reinforcing the need for comprehensive water testing in Traghen and similar communities.[23.24]

Overall, the findings support a model in which metabolic disease, environmental exposures, and nephrotoxic behaviors interact synergistically, producing patterns analogous to international CKD clusters but shaped by the unique socioeconomic and health-system context of Southern Libya.

CONCLUSION:

The findings of this comparative analysis demonstrate that the burden of chronic kidney disease in Southern Libya is shaped by a complex and uneven distribution of metabolic, behavioral, and environmental risk factors. Traghen emerged as a distinct high-risk hotspot, characterized by extremely elevated rates of diabetes, hypertension, and profoundly poor glycaemia control, patterns that far exceed those reported in neighboring municipalities and mirror the risk clustering described in international CKD and CKDu-affected regions. The coexistence of nephrotoxic behaviors—such as chronic analgesic use and unregulated herbal remedy consumption—and the presence of elevated TDS levels in local groundwater further suggest that multiple stressors may be acting in synergy to accelerate renal injury in already vulnerable populations.

These findings underscore the urgent need for geographically targeted public health strategies rather than uniform regional approaches. Priority actions should focus on strengthening chronic disease management systems, improving early detection and continuous monitoring of high-risk individuals, regulating access to nephrotoxic medications and traditional remedies, and implementing systematic water-quality surveillance in communities where chemical exposure may exacerbate underlying metabolic risk. Given the parallels with CKD clusters reported in other parts of the world, the results also highlight the need for well-designed longitudinal and case–control studies to elucidate causal pathways and quantify the interaction between metabolic, behavioral, and environmental determinants.

Taken together, this study provides the strongest evidence to date that the CKD crisis in Southern Libya is geographically concentrated and multifactorial in origin. Addressing it effectively will require integrated interventions, targeted resource allocation, and a coordinated effort across clinical, environmental, and community-level sectors to prevent further progression toward end-stage renal disease.

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