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# Prevalence of arsenic-induced skin lesions and associated factors in Ethiopia: Community-based study

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ABSTRACT

The study aimed to assess the prevalence of arsenic-induced skin lesions and associated factors among the population in the Adami Tulu Jido Kombolcha district, Ethiopia. A community-based cross-sectional study design was employed among 403 participants from June 02–20, 2022. A two-stage cluster sampling method was conducted to select study subjects. A pretested structured and semi-structured interview questionnaire and observation using a WHO flow chart were used for data collection. Data analysis was performed using SPSS version 24 statistical software for Windows. A multivariable binary logistic regression model was applied to examine the relationship between predictor variables and an outcome variable. The degrees of association between outcomes and predictor variables were assessed using ORs and 95% CIs, and P-values $< 0.05$ were considered significant. The prevalence of arsenic-induced skin lesions (arsenicosis) in the study area was 2.2% [95% CI: 1.0–3.7]. The most common arsenic-induced manifestation was keratosis (55.6%), followed by hyperpigmentation (33.3%) and hyperkeratosis (11.1%). Consumption of well water, smoking cigarettes, and chewing khat were significantly associated with arsenic-induced skin lesions. Therefore, the findings of this study should trigger further research on arsenic exposure and health risks.

## 1. Introduction

Arsenic is an extremely toxic and carcinogenic metalloid that occurs in rock, soil, water, air, and even in animals and plants [1–3]. Arsenic is known to be the "king of poisons" and the "toxic king", which reflects the acuteness of its toxic effects [4]. Today, the word "arsenic" is synonymous with "poison" [5].

Arsenic contamination is a worldwide problem and has become one of the most severe threats to the health of millions of people [6]. Currently, it is estimated that 107 countries worldwide are affected by human exposure to moderate to higher concentrations of As in groundwater [7], while the worst affected places are East Asian countries [8]. According to the World Health Organization (WHO), globally, an estimated 200 million people are exposed to arsenic through natural drinking water that exceeds the recommended value of the WHO standard [9]. This indicates that arsenic contamination of drinking water is a major global public health concern.

Presently, the effect of As on human health has become an issue of global concern, while exposure is known to cause various acute and chronic human health problems [10]. High levels of As exposure have been shown to cause acute health effects such as nausea, vomiting, abdominal pain, profuse diarrhea, renal failure, and shock [3,11–15]. Chronic ingestion of inorganic As-contaminated drinking water is considered the primary source of risk to human health [16]. Long-term exposure to low levels of arsenic in drinking water produces a wide range of health effects collectively known as arsenicosis or chronic arsenic poisoning [17]. The effects include skin lesions such as hyperkeratosis and pigmentation changes; skin cancer; lung, urinary, bladder, and kidney cancer; cardiovascular diseases; hypertension; respiratory, neurological, liver and kidney disorders; and diabetes mellitus [13,14,16–26]. Additionally, arsenicosis is defined by the WHO as a chronic health condition arising from prolonged ingestion of arsenic above the safe dose for at least six months, usually manifested by characteristic skin lesions of melanosis and keratosis, occurring alone or in combination, with or without the involvement of internal organs [27]. Considering the toxic effects and potential health risks, the WHO has revised

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and reduced its recommended maximum value for As in drinking water from 50 μg/L to a provisional value of 10 μg/L [28].

In Africa, the true magnitude of the arsenic problem and its potential impact on humans is not well studied and recognized, making Africa the least affected continent [1]. Similarly, due to limited research, the magnitude and arsenic-related risks to human health have yet to be well studied in Ethiopia. Recent studies have reported high arsenic concentrations in surface and ground waters in Ethiopia's rift valley areas, especially in the study area [12,29].

However, in Ethiopia, no studies on the prevalence of skin lesions have yet been reported. Therefore, information on the prevalence of arsenicosis or arsenic-induced skin lesions, health effects, and determinant factors is not well elucidated and identified in the study area due to limited research. Moreover, due to the delayed health effects, poor reporting, and low levels of awareness among communities, the extent of the adverse health problems caused by arsenic in drinking water is unclear and poorly documented.

Therefore, this study aimed to assess the prevalence of arsenic-induced skin lesions and associated factors among the study population in the Adami Tulu Jido Kombolcha district, Ethiopia. This is the first time such a study has been conducted in Ethiopia and East Africa. The findings of this study help provide baseline information for further study and a basis for predicting long-term health effects using the study findings and to take appropriate measures to prevent potential health risks of exposure in the study area and Ethiopia.

## 2. Materials and methods

### 2.1. Description of the study area

The study was conducted in the Adami Tulu Jido Kombolicha district, Eastern Ethiopia. The district is located in Ethiopia's central rift valley at 160 km away from Addis Ababa and 115 km from Adama, the capital city of the province. Adami Tulu Jido Kombolcha (ATJK) district has a latitude and longitude of 7°56'N and 38°43'E, respectively, with an altitude ranging from 1500 to 2000 m above sea level [30]. The location map of the study area is depicted in Fig. 1. The district's capital city is Batu town (formerly known as Ziway). Based on the current border delineation, the district has a total area of 1487.6 $km^{2,}$ which is divided into forty-six rural kebeles (the lowest administrative structure) and five urban kebeles. According to the Central Statistical Agency (CSA), the projected population for the district in 2022 was 211,827, of which 106,205 (50.1%) were male and 90,522 (42.7%) lived in urban areas [31].

The district has semiarid and arid agro-climatic zones. The area has an annual rainfall ranging from 500 to 900 mm, and the distribution is highly variable between and within years. The rainfall is bimodal, with a short rainy season from March to May and a long rainy season from June to September, followed by a dry season from October to February. The mean maximum and minimum temperatures in the study area are 27.2 and 12 °C, respectively, and the relative humidity is 60%. Agriculture is the main source of livelihood in the district. Both livestock rearing and

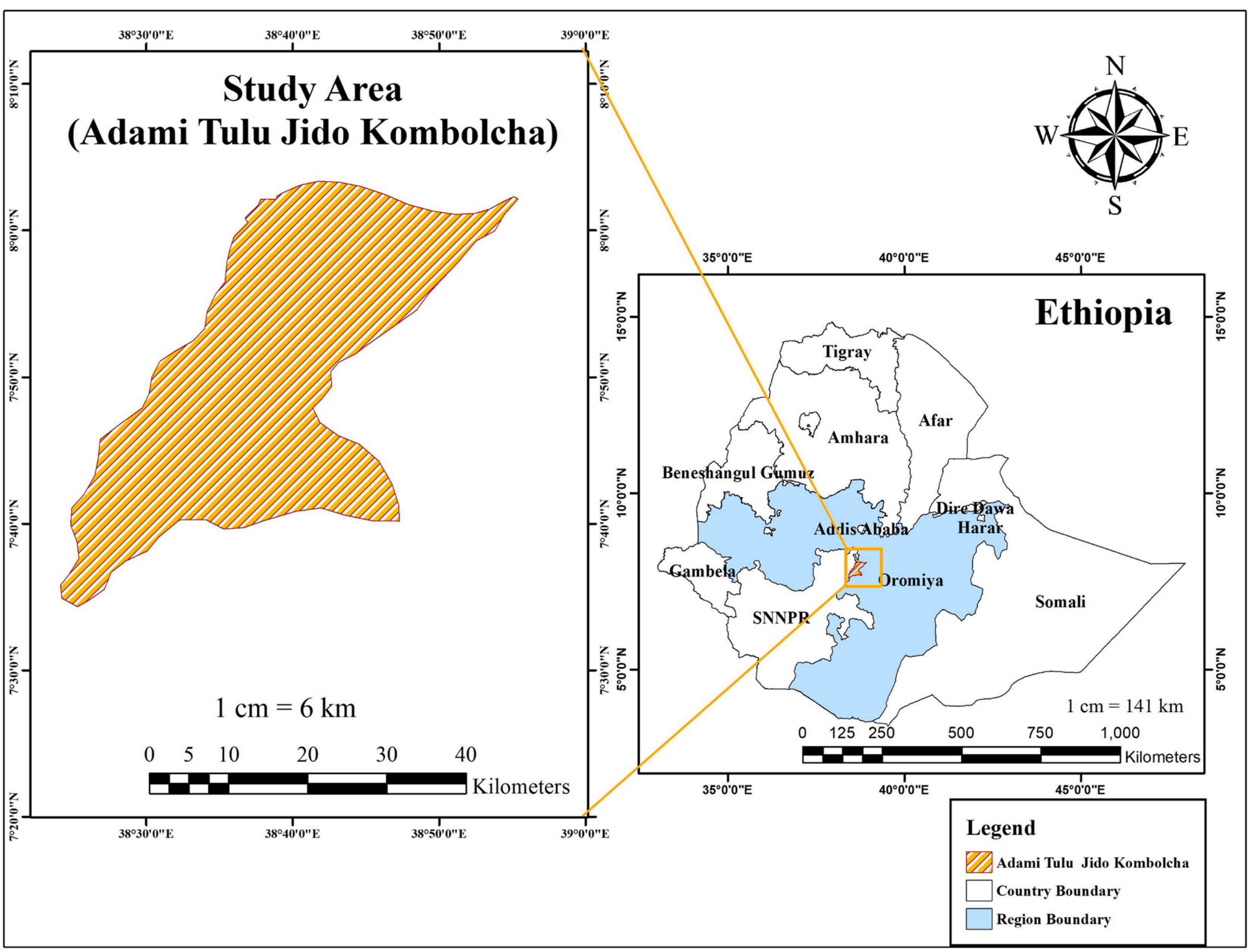


**Fig. 1.** Map of the study area.

crop cultivation (mixed farming) systems are practiced in the district [30,32,33]. Groundwater is a major source of domestic water supply in the study area, supplementary to surface water. The area is an industrial zone, and different fertilizers and chemicals are used for horticulture, floriculture, and other industrial activities, such as discharges coming directly to the environment and Lake Ziway, which is the main source of water supply for Batu town [34]. In addition, recent studies indicated that high concentrations of Arsenic had been reported in ground waters in the study area [12,29]. According to this study, the study area was identified as a high As risk area while As was detected in all selected wells, ranging from 0.6 to 73.4 μg/L(ppb) with a mean of 18.6 μg/L (ppb) and 53% of water samples had As concentrations above the WHO limit of 10 μg/L(ppb). Thus, the concentration of As in groundwater in the study area exceeded the maximum WHO recommended limit values (10 μg/L), and a high concentration of arsenic in groundwater threatens human health and poses a direct health risk to local populations in the study area.

### *2.2. Study design and study periods*

A community-based cross-sectional study design was employed to assess the magnitude and factors associated with arsenic-induced skin lesions among the study population from June 02–20, 2022.

### *2.3. Source and study population*

The source populations were populations who lived in the study area during the study period. The study populations were populations in the study area from which the sample was drawn who fulfilled the inclusion criteria.

### *2.4. Inclusion and exclusion criteria*

#### *2.4.1. Inclusion criteria*

study subjects, either male or female head of households or adults above thirty years who lived in the study area for at least ten years and were not seriously ill/hospitalized/for sickness during the time of the study.

#### *2.4.2. Exclusion criteria*

individuals residing in the study area for less than ten years or study participants whose ages were less than 30 years were excluded from the study.

### *2.5. Sample size determination*

The required sample size was determined using a single population proportion determination formula by considering 95% CI, 5% absolute precision, and a prevalence of 50%. The final sample size was 384 before considering the nonresponse rate. After adjusting for a nonresponse rate of 5%, the final sample size was 403.

### *2.6. Sampling procedure*

A two-stage cluster sampling method was employed to select study subjects. In the first stage, cluster sampling, probability proportional to size (PPS) using ENA software, was used to select kebeles/clusters. Initially, the study area was stratified by residents into five urban and forty-six rural kebeles. Accordingly, five urban kebeles and sixteen rural kebeles were randomly chosen by using simple random sampling. In the second stage, the simple random sampling method was employed to select households and study participants within the selected clusters (villages) for interviews.

### *2.7. Data collection methods*

A pretested structured and semi-structured interview questionnaire and visual observation using a WHO flow chart were used for data collection. The data collection tools were designed after reviewing the literature related to this study and based on research questions, study objectives, and variables. All data collection tools prepared in English were translated into local languages (Afan Oromo) and then back-translated to English to check the consistency with the original one. The translated tools were pretested and amended before administration in a similar setting.

### *2.8. Data collection procedure*

A four-day training, including a practical session (pretest exercise), was given to data collectors, team leaders, and other research teams. The pretest served to check the consistency and clarity of the data collection tools and case definition algorithm. The questionnaire on sociodemographic characteristics and exposure history was collected through a house-to-house visit. Kobo Toolbox online mobile application software was used to collect data using smartphones. Furthermore, visual observation and examination of suspected cases were used using a WHO flow chart and case definition algorithm by trained health professionals.

### *2.9. Study variables*

The prevalence of arsenicosis or arsenic-related skin lesions (dichotomous variable) was considered the dependent variable. The risk factors (independent or predictor variables) are categorized into two sections: sociodemographic variables and variables related to environmental factors and exposure history variables. The sociodemographic variables were residence, sex, age, marital status, education, occupation, time spent at the workplace, income, and socioeconomic status. However, the duration they stayed in the study area, source of water supply, average water consumption per day, water treatment practice, practice of vegetable gardening, use of fertilizers/or herbicides/or pesticides, frequency of taking baths, eating fish, smoking, alcohol consumption, and chewing chat are variables related to environmental factors and exposure history of the study population.

### *2.10. Operational definitions of variables*

There is no universally accepted definition for arsenicosis. However, to examine the presence of arsenic-induced skin lesions, the following case definitions defined by the World Health Organization (WHO) were used for this study [27].

- Arsenicosis is defined as a chronic health condition arising from prolonged ingestion of arsenic above the safe dose for at least six months, usually manifested by characteristic skin lesions of melanosis and keratosis, occurring alone or in combination, with or without the involvement of internal organs.
- Hyperpigmentation was characterized as raindrop-like spots of pigmentation, diffuse dark brown spots, or diffuse darkening of the skin on the limbs or trunk.
- Keratosis was characterized as either bilateral thickening of the skin of the palms of hands or the soles of feet or by nodular keratosis, that is, small protrusions that had emerged on palms and soles or occasionally on the dorsum of hands, feet, or limbs.
- Hyperkeratosis predominantly appears on palms and soles, although involvement of the dorsum of the extremities and trunk has also been described.

### *2.11. Statistical analysis*

Data analysis was performed using SPSS version 24 statistical software for Windows (IBM Corporation, USA). Univariate analysis was conducted to examine the distribution of each variable. Descriptive statistics were used to summarize the results and are reported using frequencies and percentages, and the results are presented using tables and graphs. Bivariate analyses were conducted to identify risk factors or predictor variables for arsenic-induced skin lesions and to determine the potential variables influencing the outcome variable that will be introduced into the regression model. Fisher's exact and risk estimate tests were used to check the association. The degrees of association between dependent and independent variables were assessed using ORs and 95% CIs. A P value $\leq 0.25$ significance level was used as the screening criterion for variable selection for multivariable binary logistic regression. Before running the multivariate binary logistic regression, key assumptions were checked to fit the appropriate model. The multivariate logistic regression was fitted after fulfilling its various assumptions, such as the presence of non-multicollinearity, nonnormality, and nonlinearity between the variables. The multicollinearity test was conducted using the variance inflation factor (VIF) and tolerance tests. Variance inflation factor (VIF) $> 10$ and tolerance values $< 0.20$ indicate the presence of multicollinearity, and the result of the multicollinearity test has shown the absence of multicollinearity since the VIF$<5$ and tolerance test higher than the cutoff value (0.20) for all predictor variables. Moreover, the Hosmer and Lemeshow goodness-of-fit were checked to test for model fitness, and the result was found to be insignificant (P value $>0.05$). Thus, the result revealed that the model is fit since $P > 0.05$. The results of the overall goodness-of-fit for the model suggest that the model fits very well. Finally, a multivariate binary logistic regression was conducted to examine the relationship between predictor variables and the outcome variable. The degrees of association between dependent and independent variables were assessed using ORs and 95% CIs. P values less than 0.05 were considered statistically significant in the AOR.

### *2.12. Data quality assurance*

All data collection tools were prepared in English, translated into local language (Afan Oromo), and then back-translated to English to check the consistency. Accordingly, the questionnaire was pretested in similar areas with a study population not included in the actual study to evaluate the face validity and ensure that the study participants understood what the investigators intended to elicit and revised based on the findings. Data validity and reliability are maintained through training for enumerators and other research teams, including practical exercises. Additionally, data validity and reliability were maintained through the close supervision of enumerators by the team leaders and principal investigator. Daily after fieldwork, each team submitted their questionnaire to the server, and the data were checked for completeness and consistency by the principal investigators. KoBo Toolbox software was used to flag out out-of-range values or errors during data entry. Moreover, data were checked and cleaned using SPSS software before analysis.

### *2.13. Ethical considerations*

The study was reviewed and approved by the research ethics committee of the College of Natural and Computational Sciences, Addis Ababa University, and the health research ethical review committee of Oromia Health Bureau. A support letter from the Ethiopian Institute of Water Resources, Addis Ababa University, was given to the Oromia National Regional State Health Bureau, which in turn issued a support letter to the zonal and district health offices and requested cooperation to conduct the study. Written consent was obtained from each study participant before the interview and sample collection to confirm their willingness. Privacy and confidentiality of collected information were ensured throughout the research process.

## 3. Results and discussion

### *3.1. Sociodemographic characteristics of the study participants*

A total of 403 study subjects (198 from rural areas and 205 from urban areas) participated in the study. Of the total studied population, 198 (49.1%) of the study participants were male, while the remaining 205 (50.9%) were female. The mean age of respondents was 40 years. More than half, 239 (59.3%) of the respondents were categorized as middle-aged adults, followed by 114 (28.3%) young adults and 50 (12.4%) old adults. The majority of 378 (93.8%) of the respondents were married, 16 (4%) of the respondents were single, and the remaining 9 (2.2%) of respondents were either divorced or widowed.

Regarding educational status, 113 (28.8%) of the respondents had primary education, 66 (16.4%) had secondary education, and 54 (13.4%) had a diploma and above, whereas approximately 158 (39.2%) of the respondents had no formal education. Regarding the socioeconomic status of the respondents, 151 (37.5%) and 88 (21.8%) were farmers and either governmental or private organization employees, respectively, while the remaining 55 (13.6%), 39 (9.7%) and 70 (17.3%) were merchant/traders, daily laborers, and unemployed or engaged in other activities, respectively. The average time spent at the workplace by the respondents was 44.4 hours per week. Concerning the economic status of the respondents, approximately 163 (40.4%) of the respondents were classified as lower economic status, while 192 (47.6%) and 48 (11.9%) of the respondents were classified as middle and upper economic status, respectively. .

### *3.2. Prevalence of arsenic-induced skin lesions (Arsenicosis)*

Among 403 diagnosed respondents, nine were identified as arsenicosis cases with a prevalence of 2.2% [95% CI: 1.0–3.7]. Among the

**Table 1**
Sociodemographic characteristics of the study population in Adami Tulu Jido Kombolcha District, Ethiopia, January 2023.

| Variable | Frequency | Percent% |
|---|---|---|
| Residence | | |
| Urban | 205 | 50.9 |
| Rural | 198 | 49.1 |
| Sex | | |
| Male | 198 | 49.1 |
| Female | 205 | 50.9 |
| Age (years) | | |
| Young age adults | 114 | 28.3 |
| Middle age adults | 239 | 59.3 |
| Old age adults | 50 | 12.4 |
| Marital status | | |
| Single | 16 | 4.0 |
| Married | 378 | 93.8 |
| Divorced | 8 | 2.0 |
| Widowed | 1 | 0.2 |
| Education status | | |
| Unable to read and write | 90 | 22.3 |
| Able to write and read | 68 | 16.9 |
| Primary (1–8 grade) | 113 | 28.0 |
| Secondary (9–12 grade) | 66 | 16.4 |
| Technical/Vocational Certificate | 12 | 3.0 |
| Diploma and above | 54 | 13.4 |
| Occupation | | |
| Not working | 32 | 7.9 |
| Farmer | 151 | 37.5 |
| Governmental employee | 34 | 8.4 |
| Merchant/trade | 55 | 13.6 |
| Private organization employee | 54 | 13.4 |
| Daily laborer | 39 | 9.7 |
| Other | 38 | 9.4 |
| Socioeconomic status | | |
| Upper | 48 | 11.9 |
| Middle | 192 | 47.6 |
| Lower | 163 | 40.4 |

cases, 55.6% of the study subjects with arsenicosis had keratosis, while the remaining 33.3% and 11.1% of the suspected cases had hyperpigmentation and hyperkeratosis, respectively. .

Arsenic skin lesions may serve as an indicator for arsenic-affected populations, as it is a convenient method of ascertainment [35]. Presently, there is no accepted international consensus on the criteria for the diagnosis and management of arsenicosis. Additionally, no accepted international guidelines are available for the diagnosis and management of arsenicosis, and there is no known specific treatment for arsenicosis [27,36,37]. However, nutritional status plays a critical role in antagonizing free radical species and increasing arsenic methylation. Low dietary intake of protein and micronutrients increases susceptibility to arsenic-related diseases. This could be because nutrition deficiency results in slow removal of arsenic from the body [38–42]. Thus, the influence of a correct daily diet and/or the use of some nutrient supplements, such as micronutrients and proteins, could help to reduce the damage caused by arsenicosis and protect against chronic exposure, especially for people living in contaminated areas. Therefore, since there is no specific treatment or chelating therapy for arsenicosis from long-term ingestion of As, nutrition intervention through natural dietary compounds will be recommended for the treatment of arsenic toxicity for the affected population. Skin manifestation is the primary condition leading a patient to seek medical care. Surprisingly, it is also recognized that arsenicosis may present with or without skin manifestation. The examination of skin manifestations was performed among all sampled respondents in our study from June 02–20,2022. Health professionals (BSc nurse and health officers) who have extensive experience in clinical care or patient care and who have worked in health care were hired and assigned for this study. Arsenicosis cases were detected by trained health professionals based on dermatological manifestation through direct observation of the limbs, sole, palm, trunk, and chest and exposure history of arsenic. The trained study team confirmed probable cases of arsenicosis using the WHO flow chart and case definition algorithm. Arsenicosis cases were identified by observing skin manifestations on their body. The presence of arsenical keratoses has been suggested to be a sensitive marker for the early detection of arsenicosis and is the most common manifestation preceding the development of arsenic-related skin cancer [43]. However, it is also recognized that arsenicosis may present with or without skin manifestation, and this may be so as some arsenicosis patients may not present any sign. Moreover, the characteristics of arsenic skin lesions may also vary from place to place. Likewise, different studies have used variable definitions to determine the burden of arsenic skin lesions. Thus, variable definitions used for arsenic skin lesions in different studies may make the comparison difficult [35]. On the other hand, As concentration in shallow and deep well water was measured during two seasons (dry and wet sessions). The mean concentration of As in groundwater (shallow and deep well) during the dry and wet seasons was 11.15 and 10.67 μg/L(ppb), respectively. The concentration of As in groundwater sources exceeded the WHO recommended limit values and the maximum permissible limit for Ethiopia (10 μg/L), which means As level in the study area is high. Therefore, chronic exposure to high concentrations of arsenic in drinking water in the study area is directly related to arsenic-induced skin lesions.

The prevalence rates of arsenicosis in this study were compared with those in several studies conducted in other parts of the world. Indeed, the diagnostic criteria vary from study to study. The studies were conducted from 2000 to 2022. The sample size varies from the smallest of 124 respondents in a study conducted in Nepal to the largest of 135,452 in China. The highest prevalence of 24.3% of skin lesions was reported in Burkina Faso, while the lowest prevalence of 2.2% was reported in Nepal.

The overall arsenicosis prevalence of 2.2% in this study is much lower than that reported in previous studies [35,37,44–51] but similar to that reported in Nepal [52]. Compared to other studies from Bangladesh, India, Pakistan, China, Nepal, Cambodia, and Burkina Faso, the prevalence of arsenic-induced skin lesions in the study area is low compared to studies conducted in Africa and Asia. However, in Ethiopia, no studies on the prevalence of skin lesions have yet been reported. In conclusion, the prevalence of arsenic-induced skin lesions or arsenicosis seems lower in Ethiopia than in other countries.

### *3.3. Bivariate analysis between sociodemographic variables and arsenicosis*

Among the sociodemographic variables, sex, age, education, monthly income, and socioeconomic status were not significantly related to arsenic skin lesions, while the residence of the respondent was significantly associated with arsenic skin lesions (Table 2).

### *3.4. Bivariate analysis between environmental variables and arsenicosis*

The results of the bivariate analysis showed that among the environmental factors and exposure history variables, the duration of stay in the study area, source of water supply, average water consumption per day, water treatment practice, practice of vegetable gardening, use of fertilizers/or herbicides/or pesticides, frequency of taking baths, and alcohol consumption were not significantly associated with arsenic skin lesions, while smoking and chewing "khat" were significantly associated with arsenic skin lesions (Table 3).

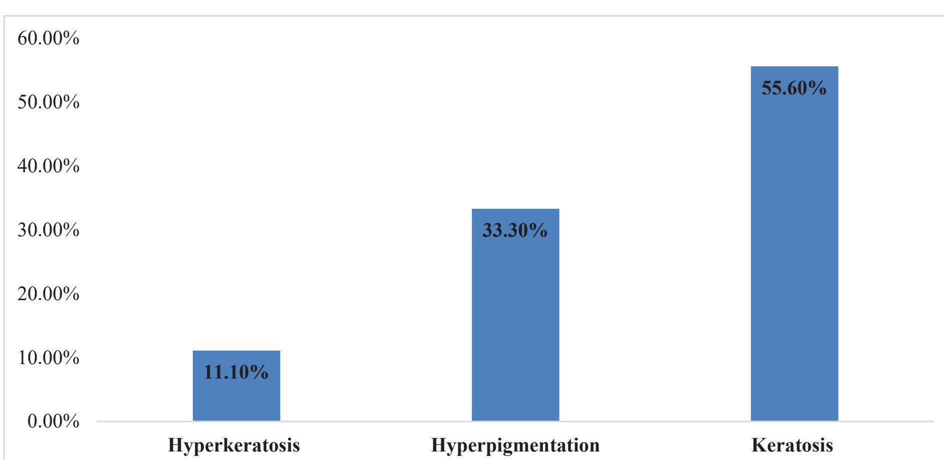


**Fig. 2.** Common manifestation of arsenicosis.

**Table 2**
Arsenic-induced skin lesions by sociodemographic risk factors among the study population in Adami Tulu Jido Kombolcha District, Ethiopia, January 2023.

| Risk factor | Arsenicosis | | | | |
|---|---|---|---|---|---|
| | Study population | Yes | No | COR 95% CI | P value |
| All | 403 | 9 | 394 | | |
| Residence | | | | | |
| Urban | 205 | 8 | 197 | 0.12 (0.01–1.00) | 0.03* |
| Rural | 198 | 1 | 197 | 1 | |
| Sex | | | | | |
| Male | 198 | 5 | 193 | 0.76 (0.20–2.90) | 0.74 |
| Female | 205 | 4 | 201 | 1 | |
| Age (years) | | | | | |
| Young age adult | 114 | 2 | 112 | 0.87 (0.07–9.87) | 0.91 |
| Middle age adult | 239 | 6 | 233 | 1.26 (0.14–10.7) | 0.83 |
| Old age adult | 50 | 1 | 49 | 1 | |
| Education | | | | | |
| Illiterate | 153 | 5 | 148 | 1.96 (0.52–7.44) | 0.32 |
| Educated | 241 | 4 | 237 | 1 | |
| Socioeconomic status | | | | | |
| Upper | 48 | 1 | 47 | 1.71 (0.15–19.3) | 0.66 |
| Middle | 192 | 6 | 186 | 2.59 (0.51–13.0) | 0.24 |
| Lower | 163 | 2 | 161 | 1 | |

* Significant at $P \leq 0.05$

### 3.5. Factors associated with arsenicosis

The results of multivariate binary logistic regression analysis showed that water consumption either from shallow or deep wells, smoking cigarettes, and chewing "Khat" or "Chat" were found to be significant predictors of arsenicosis or arsenic-induced skin lesions (Table 4).

The results of this study revealed that the odds of having arsenicosis or arsenic-induced skin lesions were 1.86 times higher among households or people who consumed well water than among households or people who did not consume water from wells (AOR=1.86; 95% CI: 1.05–2.65). This is attributed to the fact that higher arsenic concentrations are found in groundwater (shallow and deep wells) than in surface water [11,53]. Therefore, the findings of this study were consistent with other studies conducted in Burkina Faso, Nepal, China, and Bangladesh [44,46,49,52,54,55].

We also found that smoking can increase the risk of arsenicosis or arsenic-induced skin lesions. The odds of having arsenicosis or arsenic-induced skin lesions were 11 times higher among smokers than non-smokers (AOR=11.0; 95% CI: 1.62–75.6). This is attributed to the tobacco plant taking up natural inorganic arsenic, which is naturally present in soils, thus indirectly exposing smokers to the carcinogenic element. Therefore, smokers could probably be exposed to either inhaling tobacco or ingesting water contaminated with arsenic [56]. However, to our knowledge, there is no available data or report in the literature on the levels of As in Ethiopian tobacco leaves and different brands of commercially available cigarettes. Interestingly, a previous study showed that cigarettes may also contain some arsenic and estimated that approximately 0.25 μg of arsenic is ingested after smoking one cigarette [57]. Also, according to Lazarević et al. (2012), the mean contents of arsenic in tobacco was 0.15 μg/g (range <0.02–2.04 μg/g) and 0.11 μg/g in cigarettes (range <0.02–0.71 μg/g) [58]. The findings of this study were consistent with those of other studies conducted in Malaysia, Bangladesh, India, China, and Pakistan [48,54,59–62].

The risk of arsenicosis or arsenic-induced skin lesions among khat chewers was found to be significant. The odds of having arsenicosis or arsenic-induced skin lesions were 15.1 times higher among "Khat" or "Chat" chewers than among nonchewer (AOR=15.1; 95% CI: 1.22–185.7). However, the association of chewing "chat" or "khat" is not well established in the literature, but there is a practice of using insecticide and pesticide by the majority of farmers to grow their khat [63]. Likewise, there is no available report in the literature on the levels of As in Khat. Arsenic is also used to produce pesticides, insecticides, and herbicides [57,64]. Thus, the relationship between chewing khat and arsenic-induced skin lesions requires further research.

**Table 3**
Arsenic-induced skin lesions by environmental risk factors among the study population in Adami Tulu Jido Kombolcha District, Ethiopia, January 2023.

| Risk factor | Arsenicosis | | | | |
|---|---|---|---|---|---|
| | Study population | Yes | No | COR 95% CI | P value |
| All | 403 | 9 | 394 | | |
| Hours spent per week at the workplace (continuous variable) | | | | 0.96 (0.91–1.01) | 0.23 |
| How long have you been living in the study area (continuous variable) | | | | 0.98 (0.92–1.04) | 0.78 |
| Source of water supply (spring) | | | | | |
| Yes | 19 | 0 | 19 | 17.4 (16.6–18.0) | 0.99 |
| No | 384 | 9 | 375 | 1 | |
| Source of water supply (shallow and deep well) | | | | | |
| Yes | 230 | 8 | 222 | 0.16 (0.02–1.30) | 0.08 |
| No | 173 | 1 | 172 | 1 | |
| Source of water supply (piped water) | | | | | |
| Yes | 228 | 4 | 224 | 0.15 (0.02–1.27) | 0.08 |
| No | 175 | 5 | 170 | 1 | |
| Water treatment practice | | | | | |
| Yes | 89 | 3 | 86 | 0.55 (0.13–2.27) | 0.42 |
| No | 314 | 6 | 308 | 1 | |
| Average water consumption per day in liter (continuous variable) | | | | 0.70 (0.28–1.75) | 0.20 |
| How many times in a week do you bathe/shower (continuous variable) | | | | 0.95 (0.61–1.48) | 0.77 |
| Have you ever smoked a cigarette? | | | | | |
| Yes | 17 | 5 | 12 | 39.7 (9.47–167.0) | 0.000** |
| No | 398 | 4 | 394 | 1 | |
| Do you drink alcohol? | | | | | |
| Yes | 102 | 9 | 93 | 18.8 (18.0–19.4) | 0.99 |
| No | 301 | 0 | 301 | 1 | |
| Do you chew chat? | | | | | |
| Yes | 98 | 5 | 93 | 4.04 (1.06–15.3) | 0.04* |
| No | 305 | 4 | 301 | 1 | |

* Statistically significant at $P \leq 0.05$
** Statistically highly significant $P < 0.001$

### 3.6. Study limitations

The study findings only represent the situation prevailing during data collection, as the study design used was cross-sectional. However, we relied on scientific methods to obtain the data, and the analysis was

**Table 4**
Factors associated with arsenic-induced skin lesion among the study population in Adami Tulu Jido Kombolcha District, Ethiopia, January 2023.

| Variable | Arsenicosis | | | | | | |
|---|---|---|---|---|---|---|---|
| | Study population | Yes | No | P value | COR (95% CI) | P value | AOR (95% CI) |
| Residence | | | | | | | |
| Rural | 205 | 8 | 197 | 0.03* | 0.12(0.01–1.00) | 0.08 | 0.06(0.00–1.40) |
| Urban (ref) | 198 | 1 | 197 | | 1.00 | | 1.00 |
| Education | | | | | | | |
| Illiterate | 153 | 5 | 148 | 0.32 | 1.96(0.52–7.44) | 0.83 | 0.81(0.11–5.61) |
| Educated (ref) | 241 | 4 | 237 | | 1.00 | | 1.00 |
| Socioeconomic status | | | | | | | |
| Upper | 48 | 1 | 47 | 0.66 | 1.71(0.15–19.3) | 0.91 | 1.18(0.04–29.4) |
| Middle | 192 | 6 | 186 | 0.24 | 2.59(0.51–13.0) | 0.26 | 3.53(0.38–32.4) |
| Lower (ref) | 163 | 2 | 161 | | 1.00 | | 1.00 |
| Hours spent per week at the workplace (continuous variable) | | | | 0.23 | 0.96(0.91–1.01) | 0.08 | 0.92(0.85–1.01) |
| Source of water supply (shallow and deep well) | | | | | | | |
| Yes | 230 | 8 | 222 | 0.08 | 0.16(0.02–1.30) | 0.02* | 1.86(1.05–2.65) |
| No (ref) | 173 | 1 | 172 | | 1.00 | | 1.00 |
| Source of water supply (piped water) | | | | | | | |
| Yes | 228 | 4 | 224 | 0.08 | 0.15(0.02–1.27) | 0.19 | 0.12(0.00–2.99) |
| No (ref) | 175 | 5 | 170 | | 1.00 | | 1.00 |
| Have you ever smoked a cigarette? | | | | | | | |
| Yes | 17 | 5 | 12 | 0.000** | 39.7(9.47–167.0) | 0.01* | 11.0(1.62–75.6) |
| No (ref) | 398 | 4 | 394 | | 1.00 | | 1.00 |
| Do you chew chat? | | | | | | | |
| Yes | 98 | 5 | 93 | 0.04* | 4.04(1.06–15.3) | 0.04* | 15.1(1.22–185.7) |
| No (ref) | 305 | 4 | 301 | | 1.00 | | 1.00 |
| Constant | | | | | 0.001 | 0.003 | |

ref= reference category *Statistically significant at $P \leq 0.05$ **Statistically highly significant $P < 0.001$

based on robust analytical and statistical techniques, which allowed us to generate our findings. Likewise, as the study was questionnaire-based, questions that required good memory were vulnerable to recall bias. Finally, arsenicosis cases were detected based on dermatological manifestation through direct observation of the limbs, sole, palm, trunk, and chest and exposure history. The other limitation of this study was that probable cases of arsenicosis (hyperpigmentation, keratosis, and hyperkeratosis) were confirmed using the WHO case definition and flow chart, and the trained dermatologist did not confirm the cases. Thus, the findings on the prevalence of skin lesions reflect the confirmed cases as per the WHO flowchart only.

## 4. Conclusions

The findings of this study revealed that the overall prevalence of arsenic-induced skin lesions (arsenicosis) in the study area was 2.2%. In addition, among the arsenicosis cases, the most common manifestation was keratosis, followed by hyperpigmentation and hyperkeratosis. Additionally, the findings of this study confirmed that water consumption from groundwater (wells), smoking cigarettes, and chewing "khat" or "chat" were significantly associated with arsenicosis or arsenic-induced skin lesions. Therefore, the findings of this study should trigger further research. Certainly, there is a need to assess the extent of arsenic exposure and to identify the major source of arsenic exposure among the population in the study area using body biomarkers. In addition, further identification of health risks (cancer and noncancer risk) due to exposure to arsenic in drinking water in the study area will be helpful in prioritizing intervention measures. In the long term, a natural dietary compound will be recommended for the treatment of arsenic toxicity for the affected population in the study area since there is no specific treatment or chelating therapy for arsenicosis. We conclude that further effort is essential to prevent the current and future burden of arsenic toxicity.

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## Author statement

The authors declare that this research was carried out by all of us, and we all agreed to its publication.

## CRediT authorship contribution statement

**Solomon Demissie:** Conceptualization, Methodology, Investigation, Formal analysis, Software, Writing – original draft, Visualization, Funding acquisition, Resources, Project administration, Supervision. **Bizatu Mengiste:** Conceptualization, Data curation, Software, Writing – review & editing, Validation, Supervision. **Seblework Mekonen:** Conceptualization, Data curation, Software, Writing – review & editing, Validation, Supervision. **Tadesse Awoke:** Conceptualization, Data curation, Software, Writing – review & editing, Validation, Supervision. **Birhanu Teshome:** Conceptualization, Data curation, Software, Writing – review & editing, Validation, Supervision. All authors have read and agreed to the published version of the manuscript.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data Availability

Data will be made available on request.

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### *Additional information*

No additional information is available for this paper.

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