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Tourist Awareness and Perception of Fluoride Exposure in Fluoride-Endemic Regions: A Cross-Sectional Survey

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*[1]Sadiq , [2]Zhang Qichun, [3]Muhammad Salman Ahmed

[1]Associate Professor, School of Business, Shandong Xiehe University, Jinan, Shandong, China

[2]Professor, School of Economics and Management, Yango University, 99 Denglong road economic and technology development zone, Fuzhou, Fujian, China.

[3]Associate Professor, School of Economics and Management, Yango University, 99 Denglong road economic and technology development zone, Fuzhou, Fujian, China.

*** Corresponding author:**
Dr. Sadiq
School of Business, Shandong Xiehe University, Hexie Blvd,Licheng District, 250105 Jinan, Shandong, Chia.
E-mail: sadiq@mail.ustc.edu.cn

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ABSTRACT

Purpose: This study aimed to evaluate tourists' knowledge and perceptions of fluoride in regions with high fluoride concentrations, focusing on the Thar Desert. It also explored the factors influencing travel choices to these areas and examined the potential implications of fluoride exposure for tourists.

Methods: A cross-sectional study involving 251 tourists visiting the Thar Desert was conducted using convenience sampling. The survey comprised three sections: (1) demographic and socioeconomic data, (2) knowledge of fluoride, and (3) perceptions of fluoride.

Results: The data analysis revealed insights into tourists' general awareness and the factors shaping their views and decisions regarding travel to fluoride-endemic regions. Most respondents (75.7%) were between 18 and 64 years old, 35% were female, and 63% had a high school education or higher. Additionally, 63% reported staying in the area for a day. Despite these demographics, a substantial portion (67.3%) demonstrated low knowledge of fluoride, although 29.1% were aware of fluoride presence in water.

Conclusions: A significant relationship was identified between knowledge levels and educational attainment ($p < 0.001$, $\chi^2 = 32.19$). However, no significant correlation was observed between perceptions of fluoride and socioeconomic factors such as gender, age, education, or length of stay. These findings underscore the importance of government-led initiatives, in collaboration with other stakeholders, to promote public education on fluoride exposure, particularly targeting knowledge gaps linked to educational disparities.

Key-words: *Fluoride, Tourism, Knowledge, Perception, Thar Desert, Water Quality*

INTRODUCTION

Fluoride is a negatively charged ion of the element fluorine and is commonly present wtih positively charged ions such as sodium, calcium or hydrogen[1]. Numerous studies have been conducted worldwide on fluoride contamination. Fluoride contaminates water in several ways[2]; for instance, one way of fluoride contamination is through minerals having fluorine in rocks and sediments. Fluoride can be found in natural salt and freshwater bodies such as lakes and oceans. Fluoride concentration in natural water bodies is usually the result of volcanic activities in some regions[3].

Limited attention has been paid to safe water provisions in Pakistan, especially the increasing problem of fluoridate-contaminated water[4]. Numerous studies have highlighted the risk and exposure of the Pakistani population to fluoride concentrations in groundwater sources[5].

Previous research has highlighted the potential health risks associated with excessive fluoride consumption. High fluoride intake has been linked to serious health issues[6], including skeletal and dental fluorosis, disruptions in thyroid function, neurological complications, and problems with insulin secretion[7–9]. Exposure to fluoride in the early stage of teeth development may cause enamel mineralization, resulting in crystallinity gaps, disrupting protein retention, and excessive porosity[10]. A study on the relationship between IQ and excessive fluoride exposure reported fluoride's impact on children's development and learning abilities [11], highlighting a strong association between fluoride concentration in drinking water and intelligence and development abilities [12].

According to the World Health Organization, the safest level of fluoride in drinking water is 1.5mg/L, which is also the recommended and permissible limit in Pakistan for safe drinking water [4,5].

Although numerous scientific studies have been conducted on the usefulness of fluoride and its adverse effects, few people have knowledge and awareness about fluoride due to their limited exposure to academia and academic expertise. Exposure to knowledge and understanding about fluoride may result in misinterpretation and misconceptions due to their limited exposure. Misinterpretation, lack of information, and unverified concerns about fluoridation are public health challenges, as most often, community knowledge about fluoridation is based on the results of their interaction with their health practitioners[13]. Sami, Vichayanrat, & Satitvipawee [14] highlighted Pakistani people's lack of knowledge and awareness about fluoride and fluoride concentration in drinking water. Moreover, in the extent of the literature, not enough studies have been conducted on Pakistani people's knowledge and awareness of fluoride and fluoride concentration[15], especially in tourist fluoride-endemic regions such as the Thar desert.

The study assesses and evaluates tourists' knowledge and perception of fluoride exposure in regions with high fluoride concentrations. It also explores tourists' understanding of fluoride's presence, benefits, and drawbacks in drinking water in fluoride-endemic areas.

RESEARCH METHODOLOGY

A cross-sectional study was conducted using convenience sampling methodology among tourists in the Thar desert, a prominent tourist destination with a total area of 200,000km^2 covers the northwestern region of India and the southeastern region of Pakistan located at longitude 69^0,53’ and latitude 24^0,43'[4,16]. The Thar desert was selected because of the tourist inflow and its status as a fluoride-endemic region. A total of 251 people participated in the survey. Only tourists visiting the Thar desert for tourism and other recreational activities were selected and invited to participate in the survey. Residents and other entities who were not tourists were excluded from the study.

DATA COLLECTION

To check the data collection instrument's internal reliability and ensure the study participants understood the questions, a pre-test consisting of 10% of the sample size was conducted. Cronbach's Internal reliability of the data collection instrument was recorded at 0.77, indicating its internal consistency.

A close-ended structured questionnaire derived from literature was used for data collection through convenience sampling methodology. The survey questionnaire consisted of three parts: (1) demographic and socioeconomic data, (2) knowledge

of fluoride, and (3) perceptions of fluoride. The survey questionnaire was prepared in two languages, English and Urdu.

A close-ended questionnaire was used, and the respondents were asked to select 'yes,' 'no,' or 'not sure' as their answer. The 'yes' and correct answers were coded as 1. In contrast, the 'no/not sure' and wrong answers were coded as 0. Many previous studies use this scoring criterion to evaluate study participants' perceptions and knowledge levels[11,17,18].

The scoring criteria for knowledge level determined as if the respondent score is less than 50%, marked as a poor level of knowledge, scoring between 51% and 75%, marked as a moderate level of knowledge, while a score between 75% and 100% marked as a good level of knowledge[19].

The scoring criteria for perception level are determined as if the respondent score ranges between 10% and 20%, marked as very low perception; score ranges between 21% and 35%, marked as low perception; score ranges between 36% and 60%, marked as medium perception; score ranges between 61% and 85%, marked as high perception; and very high perception marked score ranges between 86% and 99%.

STATISTICAL ANALYSIS

IBM SPSS version 26 is used to analyze the data. A descriptive analysis was done to outline the distribution of sociodemographic characteristics, knowledge about fluoride, and the perception of fluoride exposure among the study participants.

RESULTS AND DISCUSSION

Sociodemographic distribution of the study participants

This study involved 251 tourists aged 18 years and above visiting the Thar desert of Pakistan. The results in Table 1 show the sociodemographic profile of the study participants. A high percentage of tourists was observed to fall between the age bracket of 18 and 64 years old compared with the 65+ age bracket. Male participants had a higher rate (65%) than females. High school and above educational level were observed to be higher than primary and no formal education. Most tourists (63%) reported visiting and having a one-day trip. Others reported visiting 2-3 days (15.9%) and 3-7 days (13.5%), while the least number (7.6%) reported visiting the area for more than 7 days.

Table 1. Sociodemographic profile of the study participants

Sociodemographic profile (N=251)	N (%)
Age	
18-64	190(75.5)
65+	61 (24.3)
Gender	
Male	163(65)
Female	88 (35)
Educational Level	
Primary	4(1.6)
Secondary	86(34.3)
High School and above	158(63)
No formal education	3(1.2)
Stay Duration	
1 day	158(63)
2-3 days	40(15.9)
3-7 days	34(13.5)
>7 days	19(7.6)

The age groups used in this study are based on the 2017 Pakistani population census. According to the Pakistan Bureau of Statistics, 96% of the population falls within the 18- to 64-year-old age bracket, while only 4% are 65 and above[17]. Male participants comprised the majority (65%) of the study sample, while female participants accounted for 35%. These findings align with the study of Sadiq & Ahmed [17], who surveyed young consumers in Pakistan, where males represented 87% of the participants. Similarly, another survey conducted by Ishaq, Xia, Rasheed, and Abdullah [17] on dairy farming in Pakistan also reported a majority (71%) of male participation. In addition, most study participants (63%) reported having a high school or above educational level compared with the other educational categories.

Knowledge about fluoride

Figure 1 depicts the results of the knowledge level about fluoride. Descriptive analysis was used to illustrate the data in terms of percentage and frequency to highlight the public knowledge level distribution about fluoride. Table 2 demonstrates the knowledge items used in this study to assess the knowledge level among tourists in the Thar desert.

The results show that most study participants (67.3%) have poor knowledge of fluoride, followed by participants with moderate knowledge of fluoride (24.7%). In comparison, only 8% reported having a good knowledge of fluoride in water. As for the source of information about fluoride, respondents were given the option to choose print media, electronic media, educational institutions, friends, or not-applicable. 77.10% picked electronic media, 41.20% picked educational institutions, 34.30% picked print media, 11.60% picked friends, and 12.60% picked not-applicable as their answer.

The results of this study highlight that electronic media is the primary source of information for most of the study participants, followed by print media and educational institutions. According to [20], electronic media is a quick, cheaper, and faster medium of getting and spreading information. Personal computers, smartphones, radio, and television are widely used electronic devices for propagation. The widespread popularity of online hypermedia platforms has established them as a dominant channel for disseminating information.

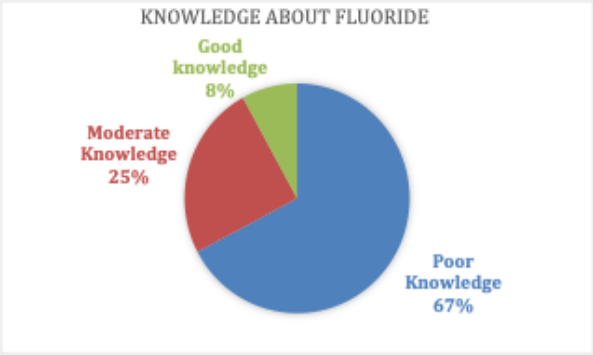

Figure 1. Knowledge about Fluoride

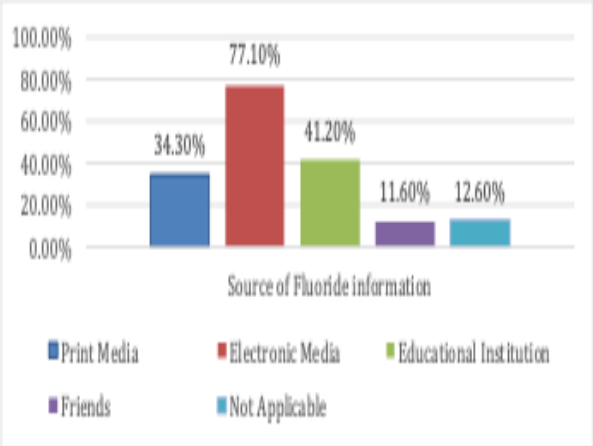

Figure 2. Source of fluoride information

Consequently, when individuals were surveyed about their exposure to information about fluoride, electronic media emerged as the most frequently cited source[21].

According to the data in Table 2, a significant proportion of study participants demonstrated knowledge about fluoride: 69% were aware of fluoride in general, 53.4% knew about fluoridated water, 50.1% understood that fluoride deficiencies could lead to diseases, and 65.3% recognized that excessive fluoride intake could also cause health issues.

Excessive fluoride intake in drinking water can lead to various health problems, including skeletal fluorosis, dental fluorosis, neural development issues, and disruptions in the thyroid gland and insulin secretion. In this study assessing knowledge of these risks, 63.7% of respondents (n=160) identified dental fluorosis as a consequence of excessive fluoride intake, followed by skeletal fluorosis (31.8%, n=80), thyroid gland problems (15.9%, n=40), insulin secretion problems (12.3%, n=31), and neural development problems (12.7%, n=32). Notably, 29.8% of participants (n=75) were unsure about the potential health consequences of high fluoride intake.

This uncertainty aligns with broader findings indicating poor fluoride knowledge. In this study, 67% of participants demonstrated poor knowledge about fluoride compared to moderate and good knowledge. Similarly, studies by Hashemipour et al.[22] highlighted significant gaps in fluoride awareness and practical application of knowledge.

Table 2 The knowledge items to assess the knowledge level of the tourists in the Thar desert. (N = 251)

Knowledge Items	Response	N (%)
Do you know what fluoride is?	Yes	173(69)
	No/Not sure	78(31)
Have you read or heard about fluoride before?	Yes	205(81.7)
	No/Not sure	46(18.3)
Where did you read or hear about fluoride?	Electronic media	193(77.10)
	Print media	86(34.30)
	Educational institutions	103(41.20)
	Friends	29 (11.60)
	Not applicable	31 (12.60)
Do you know there is fluoride in water?	Yes	177(53.4)
	No/Not sure	134(46.6)
Fluoride deficiency can cause diseases	Yes	128(50.1)
	No/Not sure	123(49.9)
High fluoride intake can cause diseases	Yes	164(65.3)
	No/Not Sure	87(34.6)
High fluoride intake can cause	Skeletal fluorosis	80(31.8)
	Dental fluorosis	160(63.7)
	Thyroid gland problem	40(15.9)
	Insulin secretion problem	31(12.3)
	Neural development problem	32(12.7)
	Not sure	75(29.8)

Previous research has documented severe dental fluorosis, characterized by brownish mottling, resulting from high fluoride intake from unregulated sources[22]. Medical professionals further emphasize that excessive fluoride can contribute to allergies, bone problems, cancer, neurological issues, and environmental and financial burdens. To mitigate these risks and prevent tooth decay, the World Health Organization (WHO) recommends a fluoride concentration of 0.5-1.5 mg/L in drinking water [4]. The Environmental Protection Agency of Pakistan is responsible and outlines different measures for safe drinking water throughout Pakistan[23]. Pakistan's provincial and local governments are mainly responsible for promoting safe drinking water provision to the general public, including delfuoridation of water.

Relationship between Sociodemographic characteristics and knowledge of fluoride

Table 3 reveals a significant association between the educational level of tourists in the Thar Desert and their knowledge of fluoride ($X^2 = 32.19$, $P < 0.001$). However, the study found no relationship between fluoride knowledge and other sociodemographic factors such as age, gender, and duration of stay. These findings align with previous research demonstrating a link between education level and fluoride knowledge. For example, Darling-Hammond et al.[24] reported that higher education-level individuals better understood fluoride and its applications. Behavior is shaped by knowledge, which progresses to application.

Education aims to cultivate this ability, enabling individuals to use established principles effectively[25], as demonstrated by the correlation between higher education and improved fluoride knowledge of tourists in the Thar Desert.

Table 3 Relationship between sociodemographic characteristics and knowledge of fluoride

Sociodemographic Characteristics	Knowledge level (%) N=251 Poor (N=169)	Moderate (N=62)	Good (N=20)	X^2	p-value (p<0.05)
Age					
18-64	126(74.6)	52 (83.9)	12 (60.0%)	2.61	0.258[b]
65+	43 (25.4)	10 (16.1)	8 (40.0)		
Gender					
Male	83 (49.1)	21 (33.9)	8 (40.0)	3.76	0.153
Female	86 (50.9)	41 (66.1)	12 (60.0)		
Educational Level					
Primary	3 (1.8)	1 (1.6)	0 (0)	32.19	0.001[b*]
Secondary	76 (44.9)	9 (14.5)	0 (0)		
High School and above	88 (52.0)	51 (82.3)	19 (95.0)		
No formal Education	3 (1.8)	1 (1.6)	0 (0)		
Stay Duration					
1 day	13 (7.7)	6 (9.7)	1 (5.0)	10.03	0.126[b]
2-3 days	23 (13.6)	12 (19.4)	1 (5.0)		
3-7 days	26 (15.4)	13 (21.0)	1 (5.0)		
>7days	107 (63.3)	31 (50.0)	17 (85.0)		

b = Fisher Exact Test. *P-value significant at p<0.05

Perception of Fluoride exposure

Figure 3 illustrates the distribution of tourist perception, while Table 4 details the perception items used in the survey questionnaire. As shown in Figure 3, most participants exhibited a high perception (34%, N=86), followed closely by very high perception (29%, N=73). 23% (N=58) reported medium perception, and 13% (N=34) reported low perception. Notably, no participants reported very low perception (0%).

Figure 4 displays the preferred sources of drinking water among the study participants. A significant portion, 46.2% (N=116), favored filtered water, while 45.7% (N=115) preferred bottled water. Only 7.9% (N=20) opted for tap water from the public water supply. Safety precautions were cited for choosing a particular water source (87.2%, N=219). Taste, smell, or color were also significant factors, mentioned by 50.2% (126 respondents). Cost and time savings were less influential, cited by 39.1% (98 respondents) (see Figure 5).

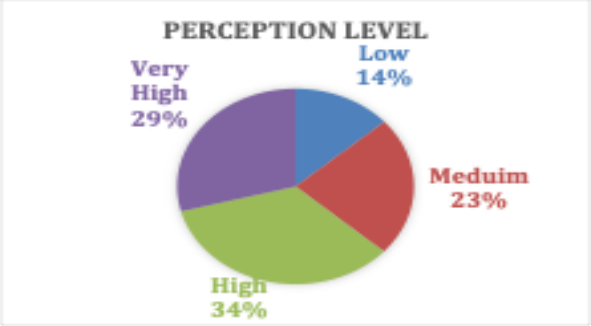

Figure 3. Perception level of fluoride exposure

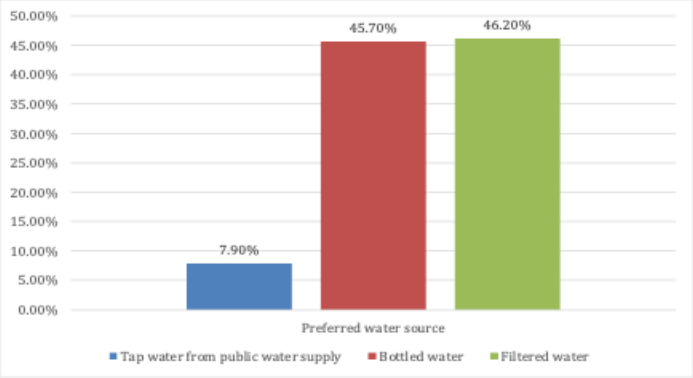

Figure 4. Preferred water source

Table 4. The knowledge items to assess the knowledge level of the tourists in the Thar desert. (N = 251)

Perception Items		N (%)
What is your common source of drinking water?	Tap water from public water supply	20(7.9)
	Bottled water	115(45.7)
	Filtered water	116(46.2)
Reason for choosing that particular source of water?	Taste, smell, or color of the water	126(50.2)
	Save money or time	98(39.1)
	Safety precautions	219(87.2)
Do you think excessive fluoride in water is not safe?	Yes	146(58.0)
	No/Not sure	105(41.8)
Do you think delfuoridation of water is important?	Yes	139(55.6)
	No/Not sure	112(44.6)
Do you think excessive fluoride in water can cause diseases?	Yes	173(69.1)
	No/Not sure	78 (31.0)
Do you support water delfuoridation efforts?	Yes	174(69.3)
	No/Not sure	77 (30.6)

Building upon the observed preference for filtered and bottled water, studies in other regions provide further context. For instance, a survey by Alsulaili et al.[25] in Kuwait revealed that residents frequently install home water filters due to their confidence in these systems and skepticism regarding the municipal water supply. Similarly, research involving German and Swiss nationals indicated a preference for bottled water, citing convenience and a lack of trust in tap water as key factors [26]. Furthermore, a study by Scherzer et al.[27] in Mexico highlighted that municipal tap water's taste, smell, and color often drive consumers toward bottled and filtered alternatives.

Pakistan reveals a similar trend to the studies from Kuwait, Germany, Switzerland, and Mexico, where concerns about tap water quality drive preferences for filtered and bottled alternatives. Surface and groundwater pollution are significant issues in Pakistan, and drinking water supplies are often poorly managed and monitored[28]. Consequently, as this study suggests, Tourists are willing to pay more for filtered and bottled water to ensure safe consumption [29], mirroring the concerns and behaviors observed in other regions.

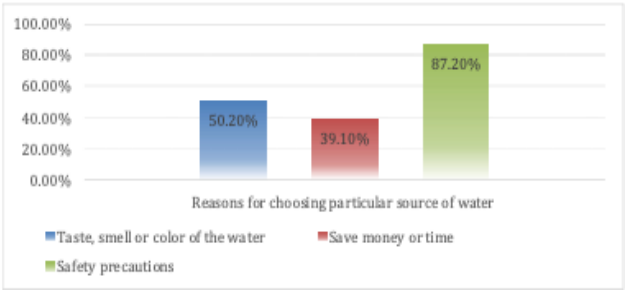

Figure 5. Reasons for choosing a particular source of water source

Studies by Kamil et al. and Aşkan et al.[30,31] suggested people value the physical characteristics of water (taste, smell, clarity) the most. However, this study found that tourists in fluoride-endemic regions prioritize safety precautions over these attributes. This may be because water consumption patterns differ significantly, with some individuals, particularly those with chronic illnesses like diabetes, drinking more significant volumes of water. Consequently, they are exposed to higher levels of fluoride. Furthermore, fluoride exposure is not limited to water; it can be found in various products, such as toothpaste and tea, potentially leading to excessive intake [32,33].

Relationship between sociodemographic characteristics and perception of fluoride

The analysis in Table 5 demonstrated no correlation between sociodemographic characteristics, such as age, gender, education level, and length of stay, and the perceived level of fluoride among tourists visiting the Thar desert in Pakistan. Consequently, the null hypothesis could not be rejected. This finding contrasts with studies by Benameur et al. and Ochoo, Valcour, and Sarkar[34,35], which reported an association between education level and perception of water quality.

Table 5 Relationship between sociodemographic characteristics and perception of fluoride

Socio demographic Characteristics	Perception level (%) N=251						
	Very Low (N=0)	Low (N=34)	Medium (N=58)	High (N=86)	Very High (N=73)	X^2	p-value (p<0.05)
Age							
18-64		27(79.4)	41(70.7)	63(73.3)	59(80.8)	7.88	0.806
65+		7 (20.6)	17(29.3)	23(26.7)	14(19.2)		
Gender							
Male		19(55.9)	31(53.4)	39(45.3)	35(47.9)	14.94	0.119
Female		15(44.1)	27(46.6)	47(54.7)	38(52.1)		
Educational Level							
Primary		1(2.9)	2(3.4)	1(1.2)	0(0.0)	14.03	0.05
Secondary		16(47.1)	20(34.5)	24(27.9)	19(26.0)		
High School and above		17(50.0)	36(62.1)	61(70.9)	54(73.9)		
No formal Education		0(0)	0(0)	0(0)	0(0)		
Stay Duration							
1 day		4(11.8)	7(12.1)	5(5.8)	3(4.1)	7.15	0.606
2-3 days		7(20.6)	15(25.9)	8(9.3)	3(4.1)		
3-7 days		8(23.5)	12(20.7)	14(16.3)	6(8.2)		
>7days		15(44.1)	24(41.4)	59(68.6)	60(82.2)		

b = Fisher Exact Test. *P-value significant at p<0.05

A potential limitation of the study could be the specificity of the perception-related questions, which might have prevented respondents from fully articulating their perspectives on fluoridation. The research intended to elicit subjective public viewpoints on fluoride rather than objective evaluations. Additionally, it is possible that the participants lacked comprehensive knowledge and awareness regarding fluoridation in water, which may have impacted their ability to express well-informed opinions on the subject.

CONCLUSIONS

This study assessed tourists' knowledge and

perception of fluoride in the Thar Desert. The study revealed that most tourists lacked knowledge of fluoride but perceived it highly. Tourists favored delfuoridation, believing that too much fluoride can cause health problems. There was a strong link between education and fluoride knowledge (p=0.001), showing that education is essential for understanding fluoride intake and avoiding health problems. However, this study had some limitations. It only looked at one point in time and focused on one area and one group of people (tourists), so the results may not apply to other situations.

RECOMMENDATIONS

To address the identified knowledge gaps and ensure the well-being of tourists in fluoride-endemic regions like the Thar Desert, the following recommendations are made:

1. **Public Health Initiatives:** Government and stakeholders should prioritize public education to bridge knowledge gaps, especially among those with limited education. These initiatives should include campaigns in multiple languages, utilizing electronic and print media, to raise awareness about fluoride exposure, its potential health effects, and safe water practices.
2. **Tourism-Specific Information:** Tourist information centers, travel agencies, and hospitality services in fluoride-endemic regions should provide clear and concise information about fluoride in the local water. This should include:
    - Information on the safety of tap water.
    - Recommendations for safe water consumption (e.g., advising bottled or filtered water).
    - Guidance on identifying safe water sources.
3. **Long-Term Impact Studies:** Future studies could investigate the long-term effects of fluoride exposure on tourists visiting fluoride-endemic regions. This research could examine potential health impacts from short-term and long-term exposure.
4. **Effectiveness of Educational Campaigns:** Future research should also test whether educational campaigns effectively increase knowledge and promote behavior change among tourists and local populations.
5. **Collaboration and Infrastructure:** Local authorities should collaborate with health organizations and tourism stakeholders to improve water quality monitoring and implement defluoridation measures where necessary. This will help ensure the provision of safe drinking water for both tourists and residents.

FUNDING

Not applicable.

CONFLICT OF INTERESTS

None.

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