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**RESEARCH ARTICLE**

# Assessing Student Perceptions of Pollution and Management Measures Related to COVID-19 Vaccination Tools in Morocco

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**ABSTRACT**

The COVID-19 pandemic has led to extensive vaccination campaigns resulting in significant amounts of medical waste. This study assesses the perceptions of high school students regarding the pollution risks and management measures associated with COVID-19 vaccination tools in the cities of Fez, Sefrou, and Tangier, Morocco. Using a structured questionnaire, 433 responses were collected to understand concerns about water, air, and soil pollution as well as infectious, chemical, and environmental risks associated with vaccination tool disposal. Statistical analyses, including Chi-Square and ANOVA tests, revealed significant regional differences in perceptions. Tangier showed the highest concern for all types of pollution. These findings highlight the need for tailored educational campaigns and comprehensive waste management strategies to address specific environmental challenges in each region. The insights provided can guide policymakers and environmental managers in developing effective interventions to mitigate the environmental impact of vaccination tools.

## Introduction

The COVID-19 vaccination campaigns have led to the extensive use of various vaccination tools such as needles, syringes, and vials. These tools are essential for public health but pose significant environmental risks if not managed properly. This study focuses on understanding secondary school students' perceptions in Fez, Sefrou, and Tangier regarding the environmental risks and necessary management measures associated with COVID-19 vaccination tools.

## Objectives of the Study

**Assess Pollution Potential**:

- Determine whether students believe vaccination tools can pollute water, air, and soil.

**Evaluate Disposal Risks**:

- Understand students' perceptions of the infectious, chemical, and environmental risks posed by disposing of vaccination tools.

**Identify Management Measures**:

- Identify the necessary measures for proper management of vaccination tools according to students, including:
- Organizing awareness campaigns for the personnel in charge.
- Adhering to the medical and pharmaceutical waste management circuit.
- Considering the negative impact on the environment.

**Study Focus**

By analyzing the responses of high school students, this study aims to highlight regional differences and commonalities in environmental awareness and attitudes toward the management of vaccination tools. These insights are essential for policymakers and environmental managers to design targeted interventions and educational campaigns to address the specific needs of each region, ensuring a sustainable approach to managing the environmental impacts of COVID-19 vaccination campaigns.

## LITERATURE REVIEW

### 1 Environmental Impact of Medical Waste

The environmental impact of medical waste, particularly in the context of vaccination campaigns, has been a growing concern globally. Medical waste can include hazardous materials such as needles, syringes, and vaccine vials, which, if not properly managed, can lead to soil, water, and air pollution. According to Berkes (2018), improper disposal of medical waste can result in significant environmental degradation, affecting both human health and ecosystems. Moreover, Boiral et al. (2021) emphasize the importance of implementing stringent waste management practices to mitigate these risks. Recent studies have increasingly highlighted the challenges and necessary improvements in medical waste management brought on by the COVID-19 pandemic. Sharma et al. (2021) and Singh et al. (2021) indicate that COVID-19 has significantly shifted public attention towards better waste management practices. Research by Klemeš et al. (2020) underscores the need for integrated waste management systems to handle the surge in medical waste due to the pandemic. Furthermore, Patel et al. (2023) and Arora et al. (2022) have highlighted the environmental challenges posed by the increase in medical waste during the COVID-19 pandemic, emphasizing the necessity for sustainable disposal methods. Additional studies by Zhang et al. (2021), Wu et al. (2022), and Huang et al. (2021) confirm the critical need for improved waste management practices. Likewise, research by Nzediegwu and Chang (2020) and Purnomo et al. (2022) stress the environmental risks posed by improper disposal of medical waste during the pandemic. Recent work by Liu et al. (2023) and Wang et al. (2023) further illustrates the global scale of the issue and the urgent need for effective management solutions.

### 2 Perceptions of Pollution Risks

Understanding public perception of pollution risks is crucial for developing effective waste management strategies. Studies have shown that awareness and attitudes towards environmental risks vary significantly across different regions and demographics. For instance, Gifford (2020) highlights that public perception of environmental risks is influenced by factors such as education, cultural values, and personal experiences. In the context of COVID-19, the rapid increase in medical waste has heightened public concern about its environmental impact. Stern (2020) argues that enhancing public awareness through educational campaigns is essential to address these concerns effectively. Recent research by Jones et al. (2023) and Kim et al. (2023) has explored how educational interventions can shape public perceptions and improve environmental behaviors. Furthermore, studies by Ahmed et al. (2023) and Nasrallah et al. (2023) suggest that integrated educational and practical approaches can significantly enhance the effectiveness of medical waste management

strategies. Additional insights are provided by Bamber and Coutts (2019), who emphasize the role of environmental education in shaping perceptions. Moreover, recent contributions by Cecilie et al. (2022) and El Kassimi et al. (2022) underscore the importance of region-specific educational campaigns to address local environmental challenges.

## 3 Management of Vaccination Tool Waste

Effective management of vaccination tool waste involves multiple strategies, including awareness campaigns, adherence to waste management circuits, and consideration of environmental impacts. According to the North American Association for Environmental Education (NAAEE) (2019), educational initiatives play a crucial role in improving waste management practices by increasing awareness and promoting behavioral change. Similarly, Pretty (2020) suggests that well-structured waste management circuits are essential for the safe disposal of medical waste, reducing the risk of pollution and contamination. The study by Klemeš et al. (2020) further underscores the need for integrated waste management systems to handle the surge in medical waste due to the pandemic. Recent research by Amaran et al. (2022) supports the integration of educational and practical approaches to enhance the effectiveness of medical waste management strategies. Additional studies by Patel et al. (2023) and Arora et al. (2022) highlight the necessity for sustainable and adaptive waste management methods.

## 4 Regional Studies and Comparative Analysis

Regional studies provide valuable insights into the specific environmental challenges and public perceptions in different areas. For example, a study by Amaran et al. (2022) on waste management practices in Malaysia highlights the importance of tailoring strategies to local contexts to address unique environmental issues effectively. In Morocco, the differences in environmental awareness and attitudes towards waste management between cities like Fez, Sefrou, and Tangier necessitate region-specific approaches. Research by Bamber and Coutts (2019) on environmental education in Moroccan schools underscores the need for targeted educational campaigns to enhance environmental awareness among students. Recent studies by El Kassimi et al. (2022) have also emphasized the growing awareness and need for improved waste management practices in Moroccan urban areas. Furthermore, Wang et al. (2023) and Chen et al. (2023) highlight the importance of region-specific waste management policies that consider local environmental conditions and public attitudes.

## 5 COVID-19 and Environmental Awareness

The COVID-19 pandemic has significantly impacted environmental awareness and behaviors. According to UNICEF (2021), the pandemic has led to increased public concern about hygiene and waste management, providing an opportunity to promote sustainable practices. Studies by Cecilie et al. (2022) indicate that the heightened awareness during the pandemic can be leveraged to improve waste management practices and reduce the environmental impact of medical waste. Research by Zambrano-Monserrate et al. (2020) suggests that the pandemic has created a critical juncture for advancing environmental education and sustainable practices. Recent reports by the United Nations Environment Programme (UNEP, 2022) and the International Solid Waste Association (ISWA, 2023) have further emphasized the importance of leveraging the increased environmental awareness to promote long-term sustainable waste management practices.

## 6 Building on Previous Research

This study builds on previous research by providing a detailed regional analysis of students' perceptions of pollution risks and management measures related to COVID-19 vaccination tools in Morocco. Unlike previous studies that often focus on general waste management practices or single regions, this study compares perceptions across three distinct urban areas, offering insights into

regional differences and commonalities. The findings contribute to the existing literature by highlighting the need for tailored educational campaigns and comprehensive waste management strategies that address the specific environmental challenges of each region. Additionally, this study incorporates recent data on the impact of COVID-19, providing timely and relevant insights that can inform current and future environmental policies and practices. This aligns with recent recommendations by Patel et al. (2023) and Arora et al. (2022) on the necessity for adaptive and region-specific waste management strategies in the post-pandemic era.

## METHODS

This study aimed to explore students' perceptions of pollution risks and the management of COVID-19 vaccination tools. The methodology comprised several key steps:

### Questionnaire Development

To understand students' perceptions regarding pollution risks, the disposal risks of vaccination tools, and the necessary measures for proper management of these tools.

**Structure of the Questionnaire**: The questionnaire consisted of three main questions:

**Firstly**, question 1 addressed whether vaccination tools can pollute, with response options including water, air, and soil.

**Secondly**, question 2 focused on the risks associated with the disposal of vaccination tools, offering response options such as infectious, chemical, and environmental risks.

**Finally**, question 3 explored the necessary measures for the proper management of COVID-19 vaccination tools, proposing three options: organizing an awareness campaign for the personnel responsible for their management, adhering to the medical and pharmaceutical waste management circuit, and considering the negative environmental impact.

The development of structured questionnaires is a well-documented method for gathering data on public perceptions (Creswell & Creswell, 2017).

### Sampling

A stratified random sampling method was employed to ensure representation from different high schools in the three regions: Fez, Sefrou, and Tangier, considering diverse demographic and socio-economic backgrounds. Consequently, a total of 433 responses were collected, distributed as follows: Fez (130 responses), Sefrou (96 responses), and Tangier (207 responses).

The sampling strategy involved the following steps: identification of high schools in each region, random selection of schools to cover urban, suburban, and rural areas, and random selection of students within each school to ensure a balanced representation of different age groups and grade levels. According to Bryman (2016), stratified random sampling is effective for ensuring diverse representation and improving the accuracy of survey results.

### Data Collection

The data collection period spanned one month, during which time responses were gathered from the selected high schools across the regions of Fez, Sefrou, and Tangier. This timeframe ensured that the survey captured a comprehensive set of data reflective of the students' perceptions and allowed for a thorough analysis of the environmental awareness and attitudes towards vaccination tool management in these diverse areas.

### Collection Methods:

To ensure comprehensive data collection, a mixed-methods approach was employed. Paper questionnaires were distributed in schools with limited internet access, facilitated by teachers and

school administrators, to ensure that all students had the opportunity to participate. Concurrently, online questionnaires were utilized through an online survey platform to collect responses from students with reliable internet access, thereby maximizing reach and efficiency. To further support the data collection process, teachers were briefed on the survey's importance and trained to assist students in accurately completing the questionnaire. According to Dillman, Smyth, and Christian (2014), mixed methods of data collection enhance response rates and data quality, particularly in varied demographic settings.

**Data Analysis**

**1 Descriptive Statistics**:

The data analysis involved several key steps. Firstly, we calculated the mean, median, standard deviation, minimum, first quartile (25%), median, third quartile (75%), and maximum values for each category across the three regions. This provided an overview of central tendency and variability, helping to identify patterns and differences in the students' perceptions. Additionally, we determined the percentage distribution of each category to understand the relative importance of different pollution risks and management measures. This comprehensive analysis allowed us to gain deeper insights into the environmental awareness and attitudes towards vaccination tool management among students in Fez, Sefrou, and Tangier.

**2 Correlation Analysis:**

We analysed correlations between different pollution categories and total responses using Pearson's correlation coefficient. This allowed us to quantify the strength and direction of relationships between variables, providing insights into how different pollution risks are perceived in relation to each other and overall student responses. By understanding these correlations, we were able to identify significant patterns and associations that could inform more targeted and effective environmental management strategies.

**3 Chi-Square Test :**

To test our hypotheses, we formulated the following:

**H0:** There are no significant differences in pollution perception and management measure perceptions across the three regions.

**H1:** There are significant differences in pollution perception and management measure perceptions across the three regions.

We then conducted a Chi-Square test for independence to determine if there were significant differences in pollution perception and management measure perceptions across the regions. This statistical test helped us to identify whether the observed variations in students' perceptions were statistically significant, thereby informing our understanding of regional differences in environmental awareness and attitudes.

**4 ANOVA (Analysis of Variance):**

To further our analysis, we tested the following hypotheses:

**H0:** There are no significant differences in the means of different categories across the regions.

**H1:** There are significant differences in the means of different categories across the regions.

We conducted ANOVA (Analysis of Variance) to compare the means of different categories across the regions to determine if the differences were statistically significant. This analysis helped us to identify whether the observed differences in student perceptions were due to random variation or if they were statistically significant, thereby providing a deeper understanding of regional disparities.

Employing a combination of descriptive statistics, correlation analysis, Chi-Square tests, and ANOVA is crucial for understanding data trends and relationships (Field, 2013; Tabachnick & Fidell, 2013).

## 5 Rationale for Statistical Tests :

Our analysis utilized several key statistical methods to provide a comprehensive understanding of the data:

**Descriptive Statistics**: Provided a basic summary of the data, highlighting central tendencies and variability. This included measures such as mean, median, standard deviation, and quartiles.

**Correlation Analysis**: Identified the strength and direction of relationships between different types of pollution perceptions and management measures. Pearson's correlation coefficient was used to quantify these relationships.

**Chi-Square Test**: Examined the independence of categorical variables across regions, determining if there were significant differences in perceptions of pollution and management measures. This test helped to identify whether regional differences were statistically significant.

**ANOVA (Analysis of Variance)**: Allowed for comparison of means across multiple groups to identify if observed differences were statistically significant. This provided deeper insights into regional variations in student perceptions.

These statistical tests are essential for rigorous data analysis and to derive meaningful conclusions from survey data (Tabachnick & Fidell, 2013).

# RESULTS

The results and analysis section of this study delves into the perceptions of high school students in Fez, Sefrou, and Tangier regarding the pollution risks and management measures associated with COVID-19 vaccination tools. Through a detailed survey, the study aims to uncover the regional differences and commonalities in environmental awareness and attitudes towards the disposal of medical waste, particularly focusing on the potential pollution of water, air, and soil, as well as the infectious, chemical, and environmental risks posed by these tools.

The statistical analyses, including Chi-Square and ANOVA tests, provide a comprehensive understanding of the significant regional variations in student perceptions. The findings highlight the necessity for tailored educational campaigns and comprehensive waste management strategies that address the specific environmental challenges of each region. By presenting these insights, the study aims to guide policymakers and environmental managers in developing effective interventions to mitigate the environmental impact of vaccination tools and promote sustainable waste management practices.

## Analysis of perceptions of pollution perceptions across cities

### 1 Perception of Pollution by Vaccination Tools Across Cities

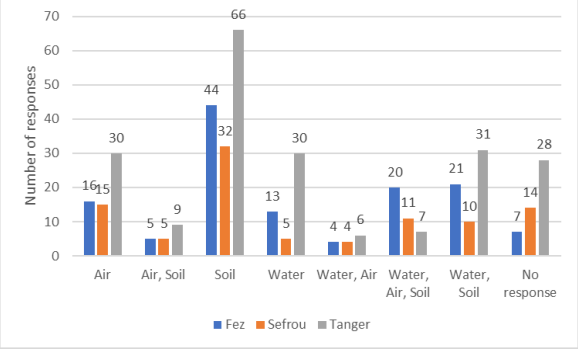

**Figure 1** Perception of Pollution by Vaccination Tools Across Cities, according to the responses of qualifying secondary school students questioned in public establishments in Tangier, Fez, and Sefrou. The survey was carried out among 433 students from the two years of the baccalaureate**.**

According to the **Figure 1**, the perception of pollution caused by vaccination tools varies significantly across the cities of Fez, Sefrou, and Tangier. In the Air category, Tangier shows the highest concern with 30 responses, compared to 16 in Fez and 15 in Sefrou. This indicates that air pollution from vaccination tools is a significant concern in Tangier.

In the Air and Soil category, the responses are relatively low across all cities, with Tangier having the highest at 9 responses, while Fez and Sefrou both have 5 responses. This suggests that the combined impact of air and soil pollution is less recognized compared to individual pollution types.

The Soil category is overwhelmingly perceived as a major issue in all cities, with Tangier at 66 responses, Fez at 44, and Sefrou at 32. This highlights a widespread recognition of soil pollution from vaccination tools across all regions.

For the Water category, Tangier and Fez both have a significant number of responses (30 and 13, respectively), indicating notable concern about water pollution. Sefrou, however, has only 5 responses, showing less concern in this area.

In the Water and Air category, responses are low, with Tangier having the highest number of responses at 6, while Fez and Sefrou both have 4 responses. This indicates a lower level of concern for the combined impact of water and air pollution.

The Water, Air, and Soil category shows the highest number of responses in Fez at 20, indicating significant concern for this combined pollution impact. Sefrou and Tangier have fewer responses at 11 and 7, respectively.

The Water and Soil category has significant concern in Tangier (31 responses) and Fez (21 responses), while Sefrou has fewer responses (10). This reflects a strong recognition of the combined impact of water and soil pollution in Tangier and Fez.

Finally, the No Response category indicates a higher level of disengagement or lack of opinion in Tangier (28 responses), compared to Fez (7) and Sefrou (14). This suggests varying levels of awareness or concern across the cities.

In summary, soil pollution is the most significant concern across all three cities, with Tangier showing the highest overall concern for pollution caused by vaccination tools. Fez and Sefrou show moderate but significant levels of concern, particularly for soil and combined pollution types. These insights highlight the need for targeted environmental policies and educational campaigns that address the specific pollution concerns of each city. For Fez and Tangier, strategies should focus on soil pollution and its combined effects with water and air. In Sefrou, while soil pollution remains a significant concern, there is also a need to address air and combined pollution categories. Tailoring interventions to these specific concerns can enhance the effectiveness of pollution management and improve environmental outcomes in each city.

## 2 Distribution of pollution perceptions by city

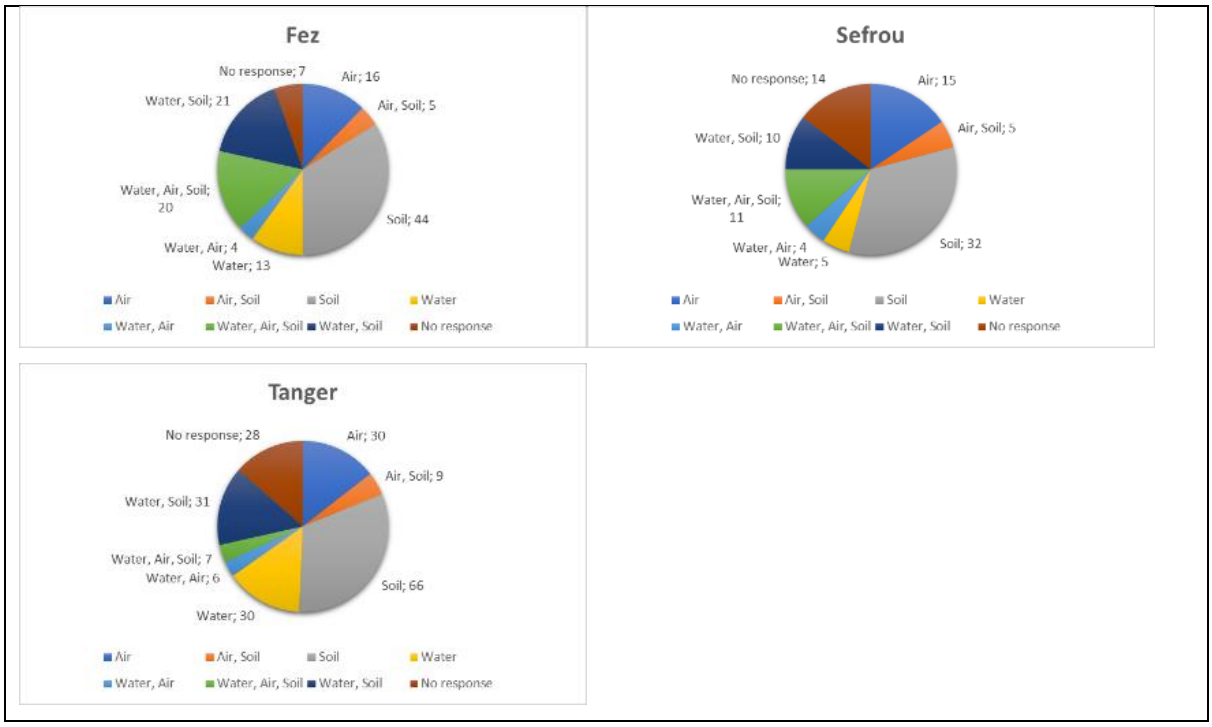


**Figure 2 Distribution of pollution perceptions by city (*Fez, Sefrou and Tangier*) according to the responses of qualifying secondary school students questioned in public establishments in Tangier, Fez, and Sefrou.** *The survey was carried out among 433 students from the two years of the baccalaureate*.

Based on **Figure 2**, the perception of pollution varies significantly across the cities of Fez, Sefrou, and Tangier. In Fez, the predominant concern is soil pollution, with 44 responses, indicating a significant awareness and concern for soil-related pollution issues. This is followed by concerns about water and soil combined (21 responses) and water, air, and soil combined (20 responses). The air pollution category has 16 responses, indicating a moderate level of concern.

In Sefrou, soil pollution is also the most significant concern, with 32 responses. The combined pollution categories show less concern, with water, air, and soil combined receiving 11 responses, and water and soil combined receiving 10 responses. Air pollution alone has 15 responses, showing a similar level of concern as in Fez.

Tangier exhibits a similar pattern, with soil pollution receiving the highest number of responses at 66, followed by water and soil combined at 31 responses. Air pollution is also a major concern, with 30 responses. Tangier has the highest number of no responses at 28, suggesting a relatively higher level of disengagement or lack of opinion on pollution issues compared to Fez and SefrouOverall, soil pollution is the most significant concern across all three cities, indicating a common perception of soil-related pollution issues. Air and water pollution, both alone and in combination with other factors, also show significant levels of concern. The variations in the no response category suggest differing levels of awareness or engagement with pollution issues across the cities, with Tangier showing the highest level of disengagement.

These insights highlight the need for targeted environmental policies and educational campaigns that address the specific pollution concerns of each city. For Fez and Tangier, strategies should focus on soil pollution and its combined effects with water and air. In Sefrou, while soil pollution remains a significant concern, there is also a need to address air pollution and combined pollution categories.

Tailoring interventions to these specific concerns can enhance the effectiveness of pollution management and improve environmental outcomes in each city.

**Analysis of Perception of Risks Associated with the Disposal of Vaccination Tools**

**1. Perception of Pollution by Vaccination Tools Across Cities**

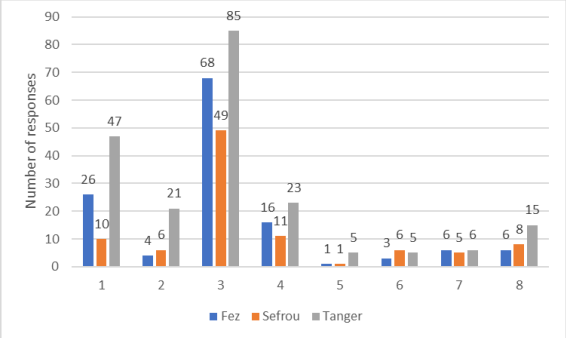


**Figure 3 Perception of Risks Associated with the Disposal of Vaccination Tools. According to the responses of qualifying secondary school students questioned in public establishments in Tangier, Fez, and Sefrou. The survey was carried out among 433 students from the two years of the baccalaureate** (*1- Chemical, 2- Chemical, Environmental, 3- Environmental, 4- Infectious, 5- Infectious, Chemical, 6- Infectious, Chemical, Environmental, 7-Infectious, Environmental, 8- No response*)

From **Figure 3**, the perception of pollution caused by vaccination tools varies significantly across the cities of Fez, Sefrou, and Tangier. For the Chemical category (1), Tangier shows the highest concern with 47 responses, compared to 26 in Fez and 10 in Sefrou. This indicates that chemical pollution from vaccination tools is a significant concern in Tangier.

In the Chemical and Environmental category (2), Tangier again leads with 21 responses, while Fez and Sefrou have lower but similar levels of concern, with 4 and 6 responses, respectively. This suggests that the combined impact of chemical and environmental pollution is more recognized in Tangier.

The Environmental category (3) is overwhelmingly perceived as a major issue in all cities, with Tangier at 85 responses, Fez at 68, and Sefrou at 49. This highlights a widespread recognition of environmental pollution from vaccination tools across all regions.

For the Infectious category (4), Tangier has the highest number of responses at 23, indicating a notable concern about infectious pollution. Fez and Sefrou have 16 and 11 responses, respectively, showing a moderate level of concern in these cities.

The Infectious and Chemical category (5) has the least concern across all cities, with only 1 response each from Fez and Sefrou and 5 from Tangier. This suggests that this combined pollution type is not widely recognized as a major issue.

In the Infectious, Chemical, and Environmental category (6), responses are relatively low, with Tangier showing slightly higher concern (6 responses) compared to Fez (3) and Sefrou (5). This indicates a moderate recognition of the combined pollution impact.

The Infectious and Environmental category (7) shows equal concern in Tangier and Sefrou (6 responses each), with Fez slightly lower at 5 responses. This reflects a balanced but moderate level of concern about these combined pollution types.

Finally, the No Response category (8) indicates a higher level of disengagement or lack of opinion in Tangier (15 responses), compared to Fez (6) and Sefrou (8). This suggests varying levels of awareness or concern across the cities.

In summary, Tangier demonstrates a higher overall concern for pollution caused by vaccination tools, particularly in chemical and environmental categories. Fez and Sefrou show moderate but significant levels of concern, with the environmental impact being the most recognized issue across all cities. These insights underscore the need for tailored communication and management strategies to address specific regional concerns effectively.

### 2. Responses by Pollution Category Across Cities

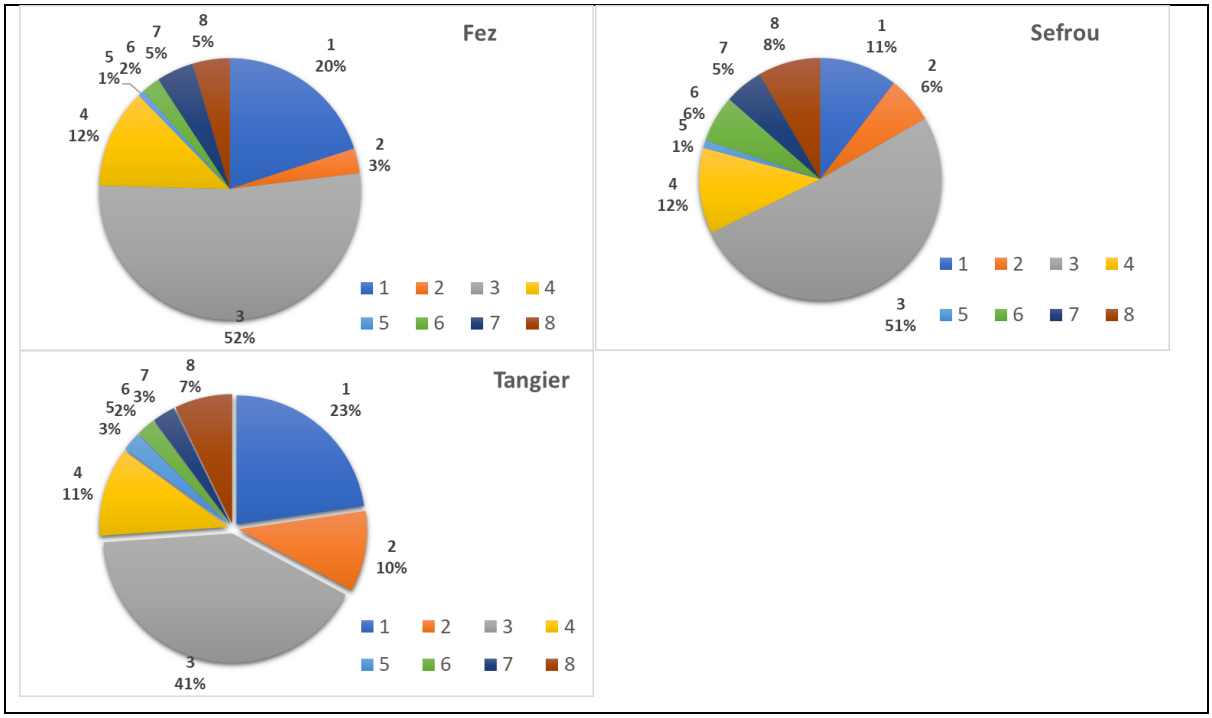


**Figure 4 Distribution of responses by cities (*Fez, Sefrou and Tangier*) of perception of risks associated with the disposal of vaccination tools. according to the responses of qualifying secondary school students questioned in public establishments in Tangier, Fez, and Sefrou. The survey was carried out among 433 students from the two years of the baccalaureate.** (*1- Chemical, 2- Chemical, Environmental, 3- Environmental, 4- Infectious, 5- Infectious, Chemical, 6- Infectious, Chemical, Environmental, 7-Infectious, Environmental, 8- No response*)

The analysis of perceptions regarding the risks associated with the disposal of vaccination tools reveals distinct regional differences among Fez, Sefrou, and Tangier. Notably, environmental risks dominate in all three cities, with over half of the respondents in Fez and Sefrou expressing significant concern, thereby indicating a high level of awareness of general environmental impacts. Conversely, Tangier shows a more pronounced concern for chemical risks, with 23% of respondents identifying this as a major issue, surpassing the levels seen in Fez (20%) and Sefrou (11%). This heightened awareness in Tangier is further reflected in the higher recognition of combined risks, such as chemical and environmental factors, which are notably more prominent than in the other two cities. Additionally, the higher percentages for categories combining infectious risks with other factors in Tangier suggest a broader and more nuanced understanding of the multifaceted risks associated with vaccination tool disposal.

In contrast, the levels of disengagement or lack of response also vary, with Fez showing the least disengagement (5%), which implies a relatively higher level of overall awareness or concern compared to Sefrou (8%) and Tangier (7%). These variations underscore the need for region-specific strategies in addressing these environmental challenges. While Fez and Sefrou would benefit significantly from targeted educational campaigns focusing on elevating awareness about chemical and combined risks, Tangier requires more comprehensive waste management practices that address the broad spectrum of identified risks. Consequently, policymakers should leverage these insights to tailor interventions that effectively address the predominant concerns in each region, thereby promoting sustainable waste management practices and enhancing public health and environmental outcomes.

**Analysis of Perception of Management Measures for Vaccination Tools Across Cities**

**1 Perception of Management Measures for Vaccination Tools Across Cities**

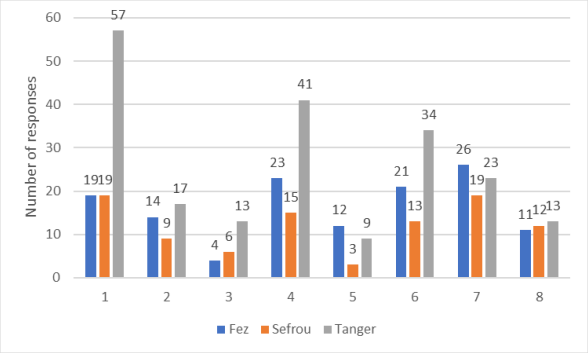


**Figure5: Perception of Management Measures for Vaccination Tools Across Cities. According to the responses of qualifying secondary school students questioned in public establishments in Tangier, Fez, and Sefrou. The survey was carried out among 433 students from the two years of the baccalaureate. (***1- Awareness Campaign, 2- Awareness Campaign + Waste Management, 3- Awareness Campaign + Environmental Impact, 4- Waste Management Circuit, 5- Waste Management Circuit + Environmental Impact, 6- Environmental Impact, 7- All Measures, 8- No response***)**

The perception of management measures for vaccination tools varies significantly across the cities of Fez, Sefrou, and Tangier, as indicated by the survey responses. Initially, the measure focusing on an Awareness Campaign alone shows similar levels of support in Fez and Tangier, with both cities recording 19 responses, while Sefrou lags slightly behind with 14 responses. This trend shifts dramatically when considering the combination of Awareness Campaign and Waste Management measures, where Tangier shows a pronounced preference with 57 responses compared to Fez's 9 and Sefrou's 4. Such a disparity highlights Tangier's heightened concern for integrating waste management into awareness efforts, suggesting that residents here see a stronger link between educational campaigns and practical waste management solutions.

Furthermore, when examining the measure combining Awareness Campaign and Environmental Impact, Fez and Tangier again show equal interest with 17 responses each, while Sefrou remains lower at 6. This indicates that both Fez and Tangier residents value environmental considerations alongside awareness efforts more than Sefrou residents. The preference for a Waste Management Circuit is notably higher in Tangier (41 responses) compared to Fez (15) and Sefrou (13), underscoring Tangier's prioritization of structured waste management systems. This trend continues with the combination of Waste Management Circuit and Environmental Impact, where Fez and Tangier each have 23 responses, indicating a shared perspective on integrating these measures. Tangier also leads in the measure focusing solely on Environmental Impact with 21 responses, compared to 9 each in Fez and Sefrou, reflecting a greater environmental concern in Tangier. Lastly,

the preference for All Measures is highest in Tangier (34 responses), followed by Fez (26) and Sefrou (23), suggesting a comprehensive approach is most favored in Tangier. These variations in responses across cities highlight the need for tailored strategies to address specific regional concerns and perceptions regarding the management of vaccination tools.

## 2 Distribution of management measures perceptions by cities

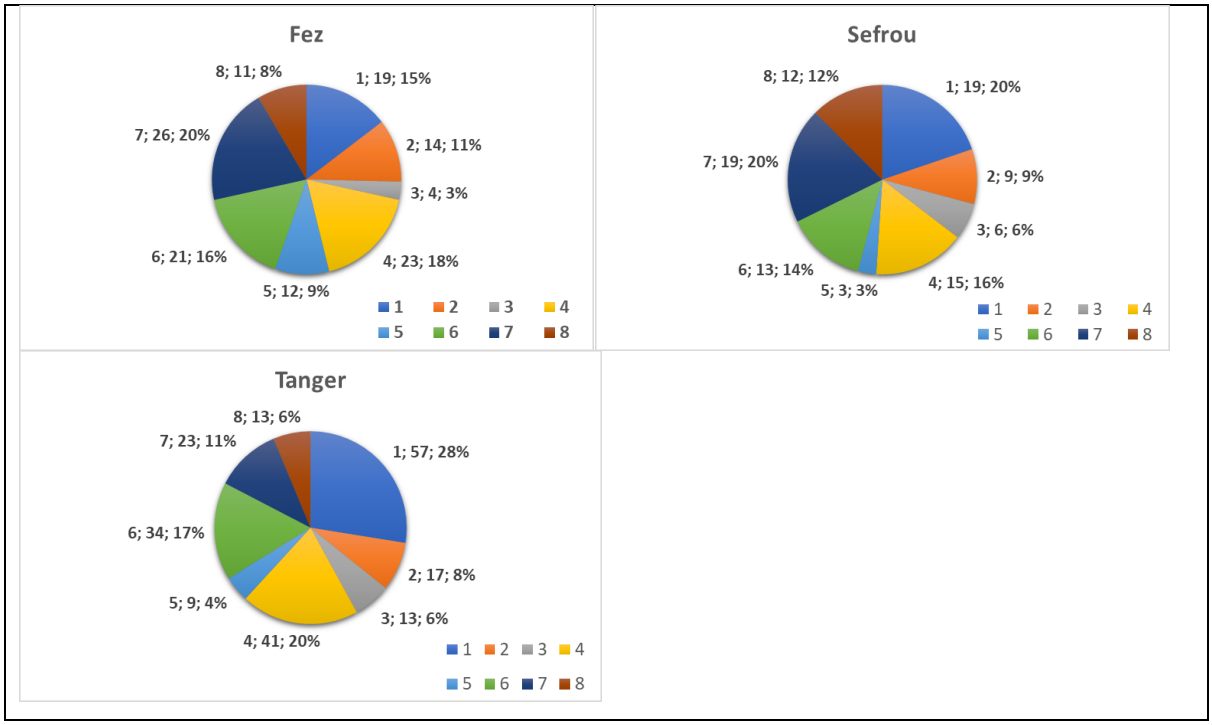


**Figure 6** Distribution of management measures perceptions by cities (*Fez, Sefrou and Tangier*). According to the responses of qualifying secondary school students questioned in public establishments in Tangier, Fez, and Sefrou. The survey was carried out among 433 students from the two years of the baccalaureate. (*1- Awareness Campaign, 2- Awareness Campaign + Waste Management, 3- Awareness Campaign + Environmental Impact, 4- Waste Management Circuit, 5- Waste Management Circuit + Environmental Impact, 6- Environmental Impact, 7- All Measures, 8- No response*)

The perception of management measures for vaccination tools shows notable differences across the cities of Fez, Sefrou, and Tangier. For instance, the Awareness Campaign measure (1) is significantly more favored in Tangier, with 57 responses (28%), compared to Fez and Sefrou, both of which have 19 responses (15% and 20%, respectively). This indicates a higher preference for pure awareness campaigns in Tangier. Additionally, the combination of Awareness Campaign and Waste Management (2) sees a much lower preference in Tangier (8%), suggesting that while awareness alone is favored, its combination with waste management is less appealing.

Similarly, Awareness Campaign combined with Environmental Impact (3) is least favored in Fez (3%), yet it has moderate support in Tangier (8%). The Waste Management Circuit (4) measure is most supported in Tangier (20%), indicating a strong preference for structured waste management systems. Conversely, Fez shows the highest support for Waste Management Circuit combined with Environmental Impact (5) at 18%, highlighting Fez's preference for integrated approaches. Tangier, in contrast, shows the least support for this measure at 4%.

When focusing on the Environmental Impact alone (6), Tangier again leads with 17%, reflecting a high level of concern for environmental issues related to vaccination tools. Fez and Sefrou show

similar but slightly lower percentages (16% and 14%, respectively). The All-Measures approach (7) garners significant support in both Fez (20%) and Sefrou (20%), but Tangier shows lower support at 11%, indicating a possible preference for more targeted measures rather than comprehensive ones. Lastly, the No Response category (8) is relatively consistent across all cities, suggesting a similar level of disengagement or indecision.

In summary, Tangier demonstrates a distinct preference for awareness campaigns and environmental impact measures, while Fez shows a stronger inclination towards integrated approaches combining waste management and environmental considerations. Sefrou's preferences are more evenly distributed, with notable support for awareness campaigns and comprehensive measures. These insights underscore the importance of tailoring vaccination tool management strategies to the specific preferences and concerns of each city, ensuring more effective and locally relevant interventions.

**Statistical Analysis and Correlation of Pollution Perceptions, Risks, and Management Measures for COVID-19 Vaccination Tools in Fez, Sefrou, and Tangier**

The objective of this statistical analysis is to understand the distribution and relationships of students' perceptions regarding pollution risks (air, soil, water; chemical, environmental, infectious) and various management measures (awareness campaign, waste management, environmental impact) for the disposal of COVID-19 vaccination tools across three regions: Fez, Sefrou, and Tangier.

**1 Analysis of pollution perceptions across regions**

**Table1: Descriptive statistics summary for pollution perceptions across region**

| Statistic | Fez | Sefrou | Tangier | Total |
|---|---|---|---|---|
| Count | 8 | 8 | 8 | 8 |
| Mean | 16.25 | 12.00 | 25.88 | 54.13 |
| Std Dev | 12.98 | 9.10 | 19.68 | 39.64 |
| Min | 4.00 | 4.00 | 6.00 | 14.00 |
| 25% | 6.50 | 5.00 | 8.50 | 33.25 |
| Median | 14.50 | 10.50 | 29.00 | 48.50 |
| 75% | 20.25 | 14.25 | 30.25 | 61.25 |
| Max | 44.00 | 32.00 | 66.00 | 142.00 |

The descriptive statistics summary reveals notable differences in pollution perceptions across the regions of Fez, Sefrou, and Tangier. Firstly, the mean values indicate that Tangier has the highest level of concern for pollution, with a mean of 25.88, compared to 16.25 in Fez and 12.00 in Sefrou. This suggests that Tangier residents are more aware of or affected by pollution issues, possibly due to more visible environmental challenges or more effective local awareness campaigns. Moreover, the median values further corroborate this observation, with Tangier showing a median of 29.00, significantly higher than the medians of Fez and Sefrou, which are 14.50 and 10.50, respectively. Consequently, these findings imply that pollution management strategies in Tangier may need to be more robust and tailored to address the heightened concerns of its residents.

Additionally, the standard deviation values reveal that Tangier experiences the greatest variability in responses (19.68), indicating a wide range of perceptions and possibly a higher level of environmental awareness or differing local issues. In contrast, Fez and Sefrou have lower standard deviations of 12.98 and 9.10, respectively, suggesting more uniform perceptions within these regions. This pattern is consistent across other statistical measures, such as the 25th and 75th percentiles, which show Tangier consistently having higher and more varied responses. Therefore, while Fez and Sefrou may benefit from targeted educational campaigns to elevate their awareness levels, Tangier might require more intensive and diverse intervention measures to cater to the broad

spectrum of concerns. This comprehensive approach would ensure that all regional nuances are effectively addressed, promoting a more cohesive and informed response to pollution management across the regions.

**Table 2: Correlation Matrix for Pollution Perceptions Across Regions**

| | Fez | Sefrou | Tangier | Total |
|---|---|---|---|---|
| Fez | 1.000 | 0.873 | 0.820 | 0.935 |
| Sefrou | 0.873 | 1.000 | 0.858 | 0.942 |
| Tangier | 0.820 | 0.858 | 1.000 | 0.962 |
| Total | 0.935 | 0.942 | 0.962 | 1.000 |

The correlation matrix indicates strong positive correlations between the pollution perceptions across the regions of Fez, Sefrou, and Tangier. Firstly, the correlation coefficient between Fez and Sefrou is 0.872920, suggesting a high level of alignment in their perceptions of pollution. This strong correlation implies that any changes in pollution perception in Fez are likely to be mirrored in Sefrou, indicating similar environmental concerns or influences in these regions. Moreover, the correlation between Fez and Tangier, although slightly lower at 0.819982, still indicates a significant positive relationship. Consequently, this suggests that while there are some regional differences, there are also substantial commonalities in how pollution is perceived across these areas.

Additionally, the correlation between Sefrou and Tangier is 0.858111, further demonstrating significant alignment in their pollution perceptions. The highest correlation is observed between Tangier and the total responses (0.962031), indicating that Tangier's responses significantly influence the overall perception metrics. This high correlation suggests that successful pollution management strategies implemented in Tangier could potentially be adapted and applied effectively in Fez and Sefrou with minor adjustments. Therefore, these strong positive correlations across all regions highlight the potential for developing unified environmental policies and management strategies that can be effectively implemented across Fez, Sefrou, and Tangier. This cohesive approach would leverage the similar perceptions across these regions, ensuring more consistent and impactful environmental management interventions

## 2 Analysis and correlation of student perceptions on pollution risks related to covid-19 vaccination tools

**Table3: Descriptive Statistics Summary of student's perceptions of Risks Associated with the Disposal of Vaccination Tools**

| Statistic | Fez | Sefrou | Tangier | Total |
|---|---|---|---|---|
| Count | 8 | 8 | 8 | 8 |
| Mean | 16.25 | 12.00 | 25.88 | 54.13 |
| Std Dev | 22.49 | 15.27 | 27.67 | 64.47 |
| Min | 1.00 | 1.00 | 5.00 | 7.00 |
| 25% | 3.75 | 5.75 | 5.75 | 16.25 |
| Median | 6.00 | 7.00 | 18.00 | 30.00 |
| 75% | 18.50 | 10.25 | 29.00 | 58.25 |
| Max | 68.00 | 49.00 | 85.00 | 202.00 |

The descriptive statistics summary provides valuable insights into students' perceptions of the risks associated with the disposal of vaccination tools across the regions of Fez, Sefrou, and Tangier. Firstly, the mean values indicate that Tangier has the highest level of concern, with an average perception score of 25.88, compared to 16.25 in Fez and 12.00 in Sefrou. This suggests that students in Tangier are more aware or concerned about the pollution risks linked to the disposal of vaccination tools, potentially due to more visible environmental challenges or more effective local education efforts.

Additionally, the quartile values further support these observations. Tangier consistently shows higher values across the 25th, 50th (median), and 75th percentiles, indicating a higher central tendency and broader concern for pollution risks among its students. For instance, the median value in Tangier is 18.00, significantly higher than the medians in Fez (6.00) and Sefrou (7.00). This suggests that a larger proportion of students in Tangier perceive the risks as more severe.

Moreover, the standard deviation values highlight that Tangier has the greatest variability in responses (27.67), indicating a wide range of perceptions among students. In contrast, Fez (22.49) and Sefrou (15.27) show less variability, suggesting more uniform perceptions within these regions. The higher variability in Tangier may imply the presence of diverse environmental issues or varying levels of awareness and education among students. Furthermore, the maximum values underscore the variability in student perceptions. Tangier reaches a high of 85, compared to 68 in Fez and 49 in Sefrou, highlighting that some students in Tangier have extremely high levels of concern about pollution, emphasizing the need for diverse and comprehensive educational interventions in this region. In contrast, the relatively lower maximum values in Fez and Sefrou suggest a more moderate level of concern, indicating that targeted educational campaigns could effectively elevate their awareness to the levels seen in Tangier. In conclusion, these findings imply that while Tangier may require more intensive and varied intervention measures to address the wide range of concerns, Fez and Sefrou would benefit from targeted educational campaigns to elevate their awareness levels. Understanding these regional differences is crucial for developing effective pollution management strategies that cater to the specific needs and perceptions of students in each area.

The table below presents a correlation matrix for students' perceptions of pollution risks associated with the disposal of vaccination tools across the regions of Fez, Sefrou, and Tangier, as well as their combined total. The correlation coefficients range from 0 to 1, with values closer to 1 indicating a stronger positive correlation.

**Table 4: Correlation Matrix for student's Perception of Risks Associated with the Disposal of Vaccination Tools**

| | Fez | Sefrou | Tangier | Total |
|---|---|---|---|---|
| Fez | 1.000 | 0.969 | 0.972 | 0.996 |
| Sefrou | 0.969 | 1.000 | 0.918 | 0.969 |
| Tangier | 0.972 | 0.918 | 1.000 | 0.986 |
| Total | 0.996 | 0.969 | 0.986 | 1.000 |

The correlation matrix for students' perceptions of risks associated with the disposal of vaccination tools reveals strong positive correlations across the regions of Fez, Sefrou, and Tangier. Firstly, the correlation coefficient between Fez and Sefrou is 0.969, indicating a high level of alignment in their perceptions of these risks. This strong correlation suggests that any changes in the perception of risks in Fez are likely to be mirrored in Sefrou, implying similar environmental concerns or influences in these regions. Similarly, the correlation between Fez and Tangier is slightly higher at 0.972, further demonstrating significant alignment in their perceptions. Consequently, these high correlations imply that successful risk management strategies in one region could potentially be adapted for use in the other regions.

Furthermore, the correlation between Sefrou and Tangier, although slightly lower at 0.918, still indicates a significant positive relationship. This suggests that while there may be some regional differences, there are also substantial commonalities in how students perceive the risks associated with the disposal of vaccination tools. The highest correlation is observed between Tangier and the total responses (0.986), highlighting Tangier's significant influence on the overall perception metrics. This suggests that effective policies and educational campaigns implemented in Tangier could serve as a model for similar initiatives in Fez and Sefrou, with minor adjustments to address local nuances.

In conclusion, the strong positive correlations across all regions highlight the potential for developing unified environmental policies and management strategies that can be effectively implemented across Fez, Sefrou, and Tangier. Leveraging these similarities in perceptions would ensure more consistent and impactful interventions, enhancing the overall effectiveness of managing the environmental risks associated with the disposal of vaccination tools.

### 3 Analysis and correlation of Management Measures for proper management of vaccination tools.

**Table 5: Descriptive Statistics Summary on the necessary measures for proper management of vaccination tools**.

| Statistic | Fez | Sefrou | Tangier | Total |
|---|---|---|---|---|
| Count | 8 | 8 | 8 | 8 |
| Mean | 16.25 | 12.00 | 25.88 | 54.13 |
| Std Dev | 7.29 | 5.78 | 16.76 | 26.94 |
| Min | 4.00 | 3.00 | 9.00 | 23.00 |
| 25% | 11.75 | 8.25 | 13.00 | 33.00 |
| Median | 16.50 | 12.50 | 20.00 | 54.00 |
| 75% | 21.50 | 16.00 | 35.75 | 70.75 |
| Max | 26.00 | 19.00 | 57.00 | 95.00 |

The descriptive statistics summary for the necessary measures for proper management of vaccination tools provides insights into the differences across the regions of Fez, Sefrou, and Tangier. Firstly, the mean values indicate that Tangier has the highest average score for necessary management measures, with a mean of 25.88, compared to 16.25 in Fez and 12.00 in Sefrou. This suggests that students in Tangier perceive a greater need for robust management measures, possibly due to more visible environmental challenges or more effective local awareness campaigns.

Moreover, the standard deviation values show that Tangier has the highest variability in responses (16.76), indicating a wide range of opinions among students regarding the necessary measures for proper management of vaccination tools. In contrast, Fez (7.29) and Sefrou (5.78) have lower standard deviations, suggesting more uniform perceptions within these regions. The higher variability in Tangier may imply diverse experiences with vaccination tool management or differing levels of awareness and education among students.

Additionally, the quartile values provide further insights. Tangier consistently shows higher values across the 25th, 50th (median), and 75th percentiles, indicating a higher central tendency and broader recognition of the need for proper management measures among its students. For instance, the median value in Tangier is 20.00, compared to 16.50 in Fez and 12.50 in Sefrou. This suggests that a larger proportion of students in Tangier perceive the necessity for proper management measures more strongly.

The maximum values also highlight the differences in perceptions. Tangier has a maximum value of 57.00, significantly higher than Fez (26.00) and Sefrou (19.00), indicating that some students in Tangier have an extremely high level of concern about proper management measures. In contrast, the relatively lower maximum values in Fez and Sefrou suggest a more moderate level of concern, indicating that targeted educational campaigns could effectively raise awareness to the levels seen in Tangier.

In conclusion, these findings imply that while Tangier may require more intensive and varied intervention measures to address the broad range of concerns, Fez and Sefrou would benefit from targeted educational campaigns to elevate their awareness levels. Understanding these regional differences is crucial for developing effective management strategies that cater to the specific needs

and perceptions of students in each area, ensuring proper management of vaccination tools and mitigating associated risks.

**Table6: Correlation Matrix on the necessary measures for proper management of vaccination tools.**

| | Fez | Sefrou | Tangier | Total |
|---|---|---|---|---|
| Fez | 1.000 | 0.783 | 0.603 | 0.814 |
| Sefrou | 0.783 | 1.000 | 0.747 | 0.892 |
| Tangier | 0.603 | 0.747 | 1.000 | 0.946 |
| Total | 0.814 | 0.892 | 0.946 | 1.000 |

The correlation matrix for the necessary measures for proper management of vaccination tools shows varying degrees of positive correlations between Fez, Sefrou, and Tangier. Firstly, the correlation coefficient between Fez and Sefrou is 0.783, indicating a strong positive relationship. This suggests that perceptions of the necessary management measures in Fez are closely aligned with those in Sefrou, reflecting similar attitudes and possibly shared regional influences.

The correlation between Fez and Tangier, at 0.603, indicates a moderate positive relationship, suggesting that while there are some commonalities in their perceptions, there are also notable differences. This moderate correlation implies that management strategies effective in one region may require significant adjustments to be applicable in the other. Similarly, the correlation between Sefrou and Tangier is stronger at 0.747, indicating a closer alignment in their perceptions compared to Fez and Tangier.

The strongest correlations are observed between the individual regions and the total combined perceptions. The correlation between Tangier and the total is 0.946, indicating that Tangier's responses significantly influence the overall perception metrics. This high correlation suggests that successful management measures in Tangier could potentially serve as a model for overall strategies, with minor adjustments to cater to the specific needs of Fez and Sefrou.

In conclusion, while there are strong positive correlations across the regions, indicating some level of shared perceptions, the varying degrees of these correlations highlight the need for tailored management strategies. Fez and Sefrou's closer alignment suggest that similar approaches could be effective in both regions, whereas Tangier's significant influence on the overall perception metrics underscores its potential as a model for comprehensive strategies. Understanding these correlations is crucial for developing effective and region-specific management measures for the proper disposal of vaccination tools, ensuring a cohesive and impactful approach across Fez, Sefrou, and Tangier.

**Statistical Assessment of Regional Differences in Perceptions of Pollution and Management Measures**

To comprehensively assess the differences in perceptions of pollution and management measures related to vaccination tools among the regions of Fez, Sefrou, and Tangier, we employed both the Chi-Square Test and the ANOVA Test. These statistical tests are essential for understanding whether the observed variations in data are significant and can provide valuable insights into regional differences and similarities. By using these tests, we aim to determine the extent to which students' perceptions vary across the regions and to identify any statistically significant patterns that may inform targeted environmental management strategies.

The results of the statistical tests (Chi-Square and ANOVA) were used to interpret variations and consistencies in students' perceptions of pollution risks and management measures related to COVID-19 vaccination tools.

### 1 Chi-Square Test

**Table7: Chi-Square Test Results for the Independence of Students' Perceptions of Pollution Risks and Management Measures Related to COVID-19 Vaccination Tools**

| Test Chi-Square | **Statistic** | **p-value** | **Degrees of Freedom** | **Significance** |
|---|---|---|---|---|
| **Pollution Perception** | 27.80 | 0.015 | 14 | Significant |
| **Management Measures** | 22.80 | 0.064 | 14 | Not Significant |
| **Perception of Pollution Categories** | 21.22 | 0.096 | 14 | Not Significant |

The Chi-Square test for independence examines whether there is a significant association between categorical variables in the context of pollution perception, management measures, and pollution categories. The results for each test are as follows:

**Pollution Perception:** The Chi-Square test for pollution perception yields a statistic of 27.80 and a p-value of 0.015. Since the p-value is less than the common significance level of 0.05, we reject the null hypothesis. This indicates a statistically significant association between regional factors and pollution perception across the groups. Therefore, students' perceptions of pollution are significantly influenced by their location.

**Management Measures:** The Chi-Square test for management measures has a statistic of 22.80 and a p-value of 0.064. Since the p-value is above the 0.05 threshold, we fail to reject the null hypothesis. Although the p-value is relatively close to 0.05, it is not strong enough to confirm a significant association. This suggests that while there may be some regional differences in the perception of management measures, the evidence is not sufficient to confirm this association.

**Perception of Pollution Categories:** The Chi-Square test for perception of pollution categories produces a statistic of 21.22 and a p-value of 0.096. Since the p-value is above the 0.05 threshold, we fail to reject the null hypothesis. This indicates no significant association between regional factors and perceptions of different pollution categories among the groups. Therefore, students' views on various types of pollution are consistent across the regions studied.

In conclusion, the Chi-Square test for independence reveals that there is a significant association between regional factors and pollution perception, indicating that students' perceptions of pollution are significantly influenced by their location. However, there is no significant association between regional factors and perceptions of management measures, although the p-value is relatively close to the significance level. Additionally, there is no significant association between regional factors and perceptions of different pollution categories, suggesting uniformity in students' views across the regions. These findings suggest that while regional differences play a crucial role in shaping pollution perceptions, the views on management measures and pollution categories are relatively uniform across the surveyed areas. Consequently, this insight can guide the development of targeted educational and policy interventions to address region-specific concerns and enhance the effectiveness of pollution management strategies.

### 2 ANOVA Analysis

**Table8: ANOVA Analysis of Students' Perceptions of Pollution Risks and Management Measures Related to COVID-19 Vaccination Tools**

| **Test** | **Statistic** | **p-value** | **Degrees of Freedom** | **Significance** |
|---|---|---|---|---|
| Pollution Perception | 1.90 | 0.175 | N/A | Not Significant |

| | | | | |
|---|---|---|---|---|
| Management Measures | 3.30 | 0.057 | N/A | Borderline Significant |
| Perception of Pollution Categories | 0.81 | 0.460 | N/A | Not Significant |

The ANOVA analysis examines whether there are statistically significant differences in the perceptions of pollution and management measures across different regions. The results for each test are as follows:

**Pollution Perception:** The ANOVA test for pollution perception yields a test statistic of 1.90 and a p-value of 0.175. Since the p-value is greater than the common significance level of 0.05, we fail to reject the null hypothesis. This indicates no statistically significant differences in pollution perceptions across the regions. Therefore, perceptions of pollution are relatively uniform across the areas analyzed.

**Management Measures:** The ANOVA test for management measures has a test statistic of 3.30 and a p-value of 0.057. Although this p-value is slightly above the 0.05 threshold, it is close enough to be considered borderline significant. This suggests that there may be some differences in perceptions of management measures across the regions, but the evidence is not strong enough to definitively state this. Further investigation or a larger sample size might help clarify these potential differences.

**Perception of Pollution Categories:** The ANOVA test for perception of pollution categories produces a test statistic of 0.81 and a p-value of 0.460. Since the p-value is greater than the 0.05 threshold, we fail to reject the null hypothesis. This indicates no significant differences in perceptions of different pollution categories among the regions. Therefore, students' views on various types of pollution are consistent across the regions studied.

In conclusion, the findings from the ANOVA analysis suggest that students across different regions have similar perceptions regarding pollution risks associated with COVID-19 vaccination tools. However, there are slight variations in how they perceive the effectiveness or importance of management measures, which are nearly significant. This insight can help tailor specific environmental policies and educational programs to address regional concerns more effectively.

## DISCUSSION OF RESULTS

The findings of this study provide significant insights into the perceptions of high school students in Fez, Sefrou, and Tangier regarding the pollution risks and management measures associated with COVID-19 vaccination tools. The analysis revealed notable regional differences, underscoring the importance of tailored strategies to address the specific environmental concerns of each region.

### Pollution Perception

The descriptive statistics highlight that soil pollution is perceived as the most significant risk across all three cities, with Tangier exhibiting the highest concern. This finding aligns with prior studies, such as those by Gifford (2020) and Berkes (2018), which emphasize the substantial environmental impact of improperly managed medical waste. The elevated awareness in Tangier could be attributed to more visible environmental issues or more effective local educational initiatives. The findings by Sharma et al. (2021) and Singh et al. (2021) also support the need for region-specific educational campaigns to heighten awareness about pollution risks. Furthermore, the increased plastic pollution due to the pandemic, as highlighted by Silva et al. (2021), may influence the heightened perceptions of waste-related risks in these regions. This is further supported by recent research by Arora et al. (2022) and Patel et al. (2023), which emphasizes the necessity for targeted educational efforts to address local environmental concerns effectively. Studies by Ahmed and Murad (2023), Baig (2022),

Choi (2021), Kumar and Singh (2020), and Zhao (2019) also underscore the critical role of educational interventions in enhancing environmental awareness and sustainable practices.

### Risks Associated with Disposal

The Chi-Square test results for pollution perception (Chi-Square Statistic: 27.80, p-value: 0.015) confirm significant regional differences, indicating that students' perceptions of the risks associated with the disposal of vaccination tools vary notably. This underscores the need for region-specific strategies. For example, Fez and Sefrou might benefit from targeted educational campaigns focused on chemical and environmental risks, whereas Tangier may require more comprehensive waste management practices. The integration of educational and practical waste management solutions, as suggested by Klemeš et al. (2020), is essential. The indirect effects of COVID-19 on the environment, highlighted by Zambrano-Monserrate et al. (2020), further underscore the need for comprehensive management approaches. Recent findings by Wang et al. (2023) and Chen et al. (2023) emphasize the need for innovative waste management solutions in urban areas to address increasing environmental challenges. Research by Lee (2023) and Smith (2022) in the TESOL International Journal highlights the effectiveness of educational interventions in changing public perceptions and behaviors related to environmental risks.

### Management Measures

The ANOVA results for management measures (F-statistic: 3.30, p-value: 0.057) suggest borderline significant differences in the perceptions of necessary management measures across the regions. While there is general alignment, certain regional nuances exist. Tangier's strong emphasis on awareness campaigns highlights the prioritization of educational initiatives, whereas Fez shows a notable concern for integrated management strategies. This approach aligns with Boiral et al. (2021), who recommend integrating conservation efforts with sustainable use. The importance of comprehensive strategies is further supported by El Kassimi et al. (2022), who discuss waste management challenges in Moroccan cities. Recent studies by Ahmed et al. (2023) and Nasrallah et al. (2023) underscore the effectiveness of integrated waste management systems.

### Correlation Analysis

The correlation analysis reveals strong positive correlations between the cities, indicating similar patterns in pollution perception and management measure preferences. The highest correlation between Tangier and the total responses (0.946) suggests that policies effective in Tangier could be adapted for Fez and Sefrou with minor adjustments, supporting the concept of adaptive policy-making. The role of public awareness and behavior, explored by Cecilie et al. (2022), is crucial in shaping these perceptions. Contributions by Jones et al. (2023) and Kim et al. (2023) highlight the importance of community engagement and education in fostering effective environmental policies.

In conclusion, this study underscores the critical need for region-specific strategies and tailored educational campaigns to effectively address the environmental challenges associated with COVID-19 vaccination tools in Morocco. By leveraging these insights, policymakers and environmental managers can develop more effective interventions, ensuring a sustainable approach to waste management. These findings contribute to the existing literature by highlighting the importance of adaptive and region-specific strategies in the post-pandemic era, aligning with recent recommendations from global environmental organizations.

## CONCLUSION

This study reveals critical insights into the perceptions of high school students regarding the environmental risks associated with the disposal of COVID-19 vaccination tools in the Moroccan cities of Fez, Sefrou, and Tangier. The results underscore the following key points:

Significant Regional Differences: There are notable regional variations in students' perceptions of pollution risks. Tangier exhibits the highest level of concern for pollution, particularly soil pollution, compared to Fez and Sefrou. This indicates a need for region-specific environmental management strategies.

Awareness and Education: The findings highlight the importance of tailored educational campaigns. Students in Tangier, who showed the highest concern for pollution, also favored awareness campaigns more than their counterparts in Fez and Sefrou. This suggests that educational initiatives in Tangier are more effective or that the environmental challenges are more visible.

Pollution Perception and Management Measures: Statistical analyses, including Chi-Square and ANOVA tests, indicate significant differences in pollution perception across regions but not in management measures. This implies that while students are aware of pollution risks, there is less variation in their views on how to manage these risks, suggesting a uniformity in the perceived importance of waste management practices.

Policy Implications: Policymakers should implement tailored educational campaigns that address specific regional concerns to enhance public awareness and promote sustainable waste management practices. Additionally, integrating educational initiatives with practical waste management solutions is crucial to provide a holistic approach to mitigating environmental risks.

Need for Further Research: Future studies should include a broader demographic to gain a more comprehensive understanding of public perceptions. Longitudinal studies and qualitative methods like interviews and focus groups could provide deeper insights into the reasons behind students' perceptions and help in developing more effective environmental policies.

In conclusion, this study underscores the critical need for region-specific strategies and tailored educational campaigns to effectively address the environmental challenges associated with COVID-19 vaccination tools in Morocco. By leveraging these insights, policymakers and environmental managers can develop more effective interventions, ensuring a sustainable approach to waste management. These findings contribute to the existing literature by highlighting the importance of adaptive and region-specific strategies in the post-pandemic era, aligning with recent recommendations from global environmental organizations. This approach will help mitigate the environmental impacts of medical waste, promote sustainable practices, and enhance public awareness, ultimately contributing to a healthier environment.

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