FLUORIDE

Quarterly Journal of the International Society for Fluoride Research Inc.

Management Science Approaches to Sustainability Strategies Against Hydrogen Fluoride Affecting Vegetation from Peri-Urban Brick Kilns of South Asia

Unique digital address (Digital object identifier [DOI] equivalent):
https://www.fluorideresearch.online/epub/files/270.pdf

Anwar Kamal Khan,[1*] Yajuan Dong,[2] Mehboob ul Hassan,[3] Azmat Ali,[4] Shah Saud[5]

1: PhD, School of Economics and Management-Chang'an University Xi'an, Shaanxi Province, PR China

2: Associate Professor, School of Economics and Management-Chang'an University Xi'an,710064, PR China

3: Professor, Department of Economics,
College of Business Administration,
King Saud University, P.O. Box 7115 Riyadh, Kingdom of Saudi Arabia.
Email: mehassan@ksu.edu.sa
ORCID: 0000-0002-3453-695X

4: MSc, Department of Agricultural Chemistry & Biochemistry, University of Agriculture, Peshawar, Pakistan

***Corresponding author:**
Anwar Kamal Khan
PhD.School of Economics and Management-Chang'an University
Xi'an, 710064,PR China
Email:
anwarkamalkhan@chd.edu.cn

Accepted: 2024 May 7
Epub as e270: 2024 May 20

ABSTRACT

Purpose: The purpose of the study was to explores sustainable management strategies against hydrogen fluoride (HF) emissions from brick kilns, which are a significant source of environmental pollution in South Asia, particularly affecting peri-urban agricultural areas. Despite the reliance on traditional fuel sources that exacerbate HF release during brick production, this study investigates alternative practices that could mitigate these harmful emissions.

Methods: The survey encompassed approximately 50 brick kilns, including both brick kiln owners and farmers. The current knowledge and understanding of the local farmers and community regarding the damage caused by HF and the effective strategies to reduce its impact and to devise the implementation plan for the already approved government policy in the region for air pollution from brick kilns and its impacts on agriculture

Results: The study uncovered findings and outcomes regarding the previous study (Hamd et al, 2012) and revealed that the air pollution situation has not improved in last two deades. The study finds that there are no advanced filtration technologies, transitioning to cleaner fuels, and improving agricultural practices to reduce air pollution from birck kilns, with no regular monitoring and maintinence and awareness of the community and brick kiln workers about the toxic exposure of crop to HF.

Conclusions: The study suggests implementing advanced filtration technologies, transitioning to cleaner fuels, and improving agricultural practices by using HF-resistant crop varieties. Additionally, it emphasizes the importance of regular monitoring and maintenance of kiln operations, the establishment of buffer zones, and enhanced community and worker education to reduce exposure to HF. The findings aim to inform policy measures and promote the adoption of sustainable practices that not only reduce HF pollution but also protect the livelihoods of local farming communities.

Key-words: hydrogen fluoride, brick kilns, air pollution, sustainable management, environmental impact, agricultural practices, South Asia, Peshawar

INTRODUCTION

Background information on fluoride pollution

Fluoride (F) is a reactive element in the environment that is found in soil and water abundantly and also in the air. The earth crust contains around 0.077% of F among the total amount of elements[1,2]. The main sources of F phosphate fertilizer, ceramic factories, aluminum smelters, brick kilns factories and volcanic eruption[3,4]. Consequently, F has been unrecognized pollutant compared to ozone (O_3) that can damage agricultural crops and fruit orchards in developing countries, which poses a serious threat to the environment ant and regional food security[5,6].

Often found in cluster just outside many cities of South Asia, brick kilns are one of the fastest growing sectors but thought to be the major source of air pollution in South Asia. After China and India, Pakistan is the third country in brick production in the world. Pakistan along with Bangladesh produce 2/3rd of the global bricks production[7]. Due to which it is the main source of atmospheric pollution causing widespread environmental impacts on humans, animals as well as plants[7].

HF Pollution from Brick Kilns in Pakistan

The presence of hydrogen fluoride (HF) emitted from brick kilns in South Asia poses a significant risk to peri-urban agriculture in the region, particularly in Pakistan. This is due to the proximity of these brick kilns, which are located just outside major cities. The brick kilns are inadequately regulated and utilize substandard fuel, resulting in the release of carbon monoxide (CO), sulfur dioxide (SO2), and HF. While the first two air pollutants contribute to climate change and environmental pollution, HF is particularly phytotoxic as it is primarily released from clay bricks during the firing process in brick manufacturing. The clay inherently contains fluoride in concentrations ranging from 20 to 1000 milligrams per kilogram. Nevertheless, the soil in polluted areas has been discovered to have a high F content, reaching up to 300 mg/kg on a dry basis[8,9]. Fluoride is extracted from the soil when the fire temperature exceeds 950^{o}C. Once released, it predominantly reacts with hydrogen to produce hydrogen fluoride.

Several studies have reported wide spread HF damage to crops in Pakistan by Ahmad[10]; Ahmad[11]; Wahid[12] and Saleem[13]. These studies emphasized on the HF concentration near the brick fields and its toxicity to vegetation. Ahmad[10,11] was the very first studies conducted in Peshawar on brick kiln pollution. They reported that HF concentration near the brick kilns were high enough (0.3µm/g) as shown in Figure 1 for a longer duration to cause foliar injury to fruit orchards of plum and apricot (Figure 2) and significant reduction in wheat yield compared. Wahid[12] and Saleem[13] reported negative effects of HF on mango and tomato, respectively.

The objective of the study was to conduct a survey, building upon previous research, in order to evaluate the present state of pollution caused by brick kilns. The study aimed to propose sustainable management approaches for reducing the release of harmful emissions, particularly HF, from brick kilns. These approaches would be implemented through government policies addressing air pollution from brick kilns in and around Peshawar city.

MATERIAL AND METHODS

Project area

A survey was undertaken in the brick kilns fields to assess the present state of air pollution's impact on the environment, particularly on the agricultural crops in the surrounding areas of Peshawar. There are approximately 450 brick kilns that operate throughout the year in the suburban areas of Peshawar city. Peshawar is located at 34^{o}01'N 71^{o}35'E in Pakistan at an elevation of 510m.

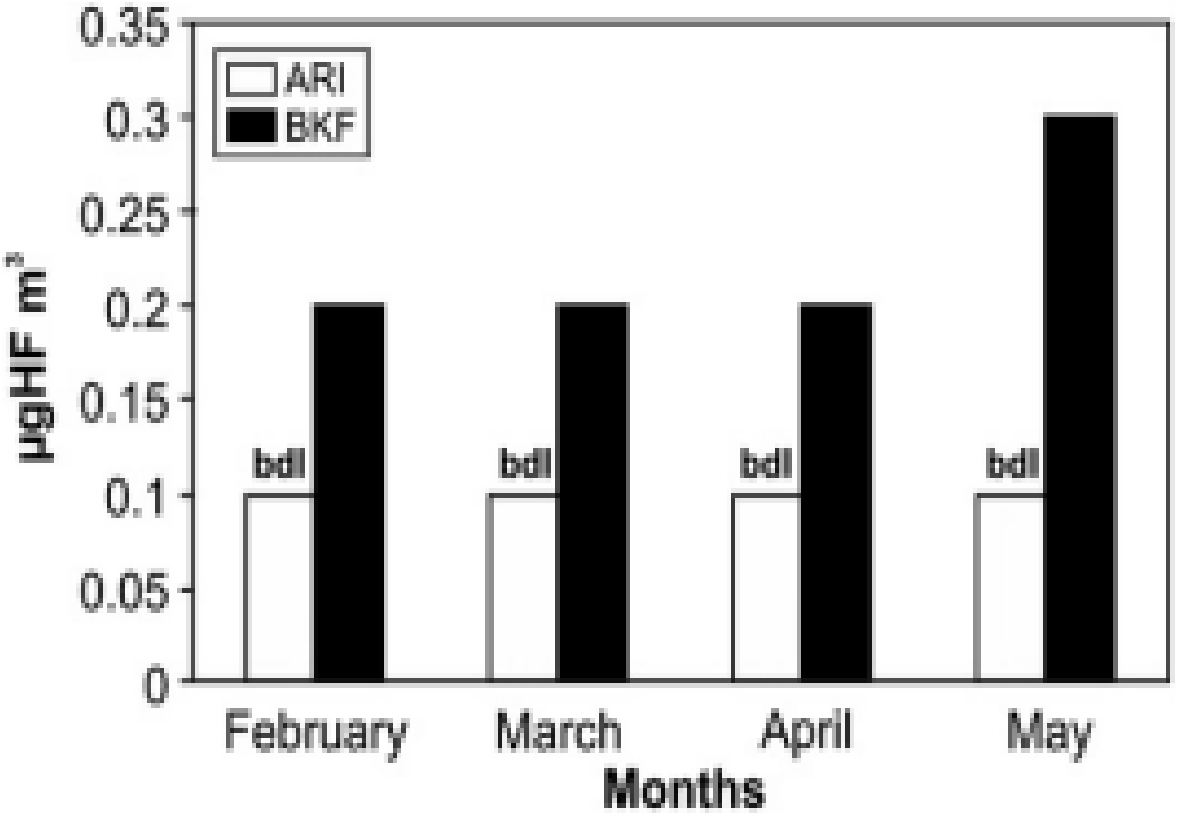

Fig 1: The air concentration of hydrogen fluoride (HF) measured at the ARI and BKF sites[10]. The findings indicated HF levels were below the detection limit of 0.1 mg/m3, denoted as 'bdl' (below detection limit). This data highlights the effectiveness of measures implemented to control HF emissions in these areas during the specified period.

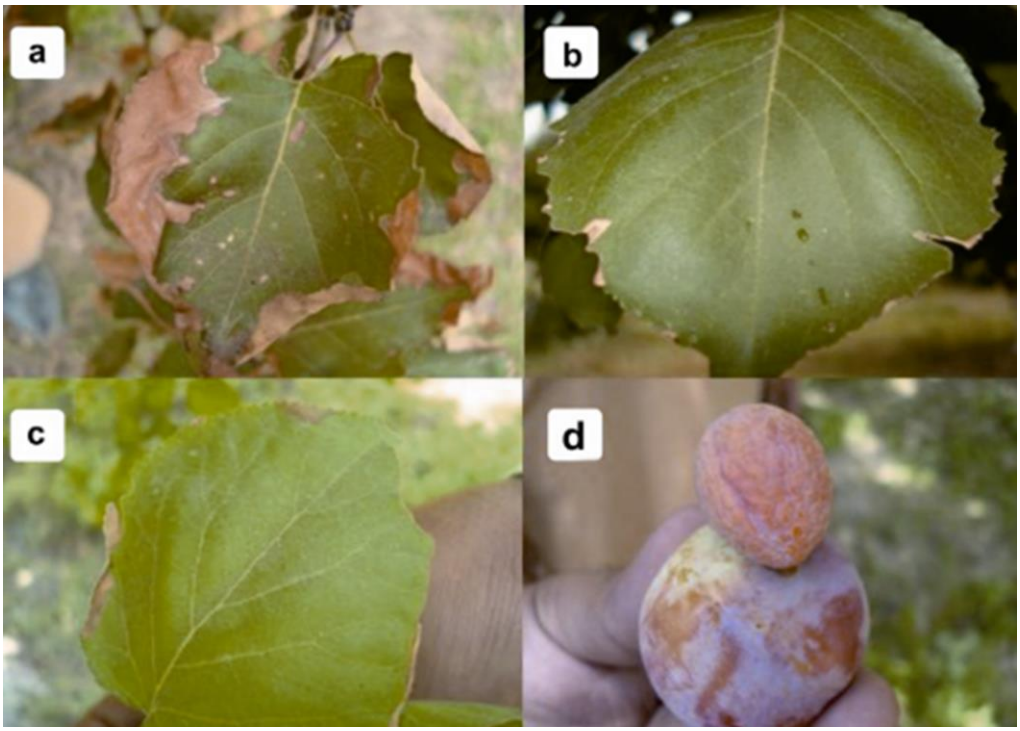

Fig 2: Typical fluoride foliar injury seen in the selected area: (a) Necrosis in form of severe injury to leaf margins and tip burn to apricot at brick kilns kiln site; (b & c) lower apricot foliar injury at control sites; (d) Shrinkage of plum fruit prematurely at brick kiln site[10]

Fig-3: Map of Peshawar {Source:Google earth}

The objective of the study was to conduct a survey, building upon previous research, in order to evaluate the present state of pollution caused by brick kilns. The study aimed to propose sustainable management approaches for reducing the release of harmful emissions, particularly HF, from brick kilns. These approaches would be implemented through government policies addressing air pollution from brick kilns in and around Peshawar city.

MATERIAL AND METHODS

Project area

A survey was undertaken in the brick kilns fields to assess the present state of air pollution's impact on the environment, particularly on the agricultural crops in the surrounding areas of Peshawar. There are approximately 450 brick kilns that operate throughout the year in the suburban areas of Peshawar city. Peshawar is located at 34°01'N 71°35'E in Pakistan at an elevation of 510m.

The prevailing wind direction is mostly from the south. The brick kiln area is located on the western side of the city, covering an area of approximately 15 square kilometers. The region primarily consists of arable land, benefiting from ample water supply from the nearby Warsak Dam. The bricks are highly sought after due to the advantageous clay composition in the soil and the demand from Afghanistan. Due to the high demand, the brick kiln resorts to using low-grade coal, used engine oil, and other household waste such as used clothes, shoes etc as fuel source to fire the kilns.

The Conversation survey

The survey encompassed approximately 50 brick kilns, including both brick kiln owners and farmers. The conversation included inquiries regarding the specific types of fuel being utilized to power the brick kilns and the reasons behind their selection. Is advanced filtration technology being employed to capture, reduce, and neutralize HF before it is released into the atmosphere? Is there a transition occurring from coal combustion to cleaner alternative fuels such as natural gas or agricultural waste biomass in order to reduce atmospheric pollution? The utilization of additives such as lime and alumina in the raw materials serves the purpose of diminishing the presence of HF and averting its emission during the brick firing process. Is there regular monitoring of HF and other pollutants and their effects on nearby crops using a modern air quality monitoring system?

Additionally, is there regular inspection and maintenance of kiln equipment to ensure minimal performance and emissions? Do brick kilns on agricultural lands have buffer zones, such as natural or artificial barriers like tall trees, to reduce vegetation

exposure to HF and other noxious gases? These barriers can effectively capture HF particulates, thereby protecting crops from substantial damage caused by HF.

What is the level of education among farmers in the affected areas regarding the damage caused by HF to their crops, and are they knowledgeable about the crop varieties that are resistant to HF pollution and toxicity? Implement protective measures by constructing greenhouse structures to provide a barrier for F sensitive crops, effectively shielding them from direct exposure to HF and other gases. Are they willing to modify planting schedules and locations in order to avoid the hours with the highest emissions or proximity to the brick kilns?

The current knowledge and understanding of the local farmers and community regarding the damage caused by HF and the effective strategies to reduce its impact. What is the level of interest among the local community in monitoring air quality and reporting violations to regulate air pollution?

Is there a government-set threshold level for HF emissions from brick kilns that needs to be checked? Will the government implement any policies to encourage brick kiln owners to adopt cleaner technologies and practices, such as providing grants, subsidies, and tax breaks?

RESULTS AND DISCUSSION

The subsequent observations were made from the present survey conducted in the brick kiln regions of Peshawar:

Status of Air pollution and Reduction Technologies

The survey conducted among brick kiln owners and local farmers provides a comprehensive assessment of the pollution emanating from brick kilns. Ahmad[10] reported observable consequences of HF foliar injuries on various crops and fruit orchards. The leaf injuries exhibited characteristic symptoms of tip burn necrosis and chlorosis. Additionally, they stated that summer crops exhibit greater susceptibility to winter crops. Apricot, plum, and mango experience significant harm due to high levels of HF pollution. According to Table 1 (Ahmad[10]), maize and tomato have low susceptibility to HF injuries, while peach fruit is highly resistant to HF pollution.

Table 1: The extent of injury symptoms at the five sites in May 2008. The injury to leaves was categorized into no injury, little injury, significant injury and severe injury. The BKF and Haya (Hayatabad) sites were close to the brick kiln area; the AUP, ARI and Charsadda (Char) sites were further away (Ahmad[10])

Site	Plant species	No injury	Little injury	Significant injury	Severe injury
BKF	Apricot				X
	Plum				X
	Peach	X			
	Maize		X		
	Tomato		X		
Haya	Mango				X
AUP	Apricot		X		
	Plum		X		
	Maize	X			
	Tomato	X			
ARI	Apricot		X		
	Plum		X		
	Peach	X			
	Maize	X			
	Tomato	X			
Char	Apricot	X			
	Plum	X			
	Mango	X			
	Peach	X			

Based on the discussion with brick kiln owners, it was evident that they are unaware of the latest technology that can effectively mitigate air pollution. They possessed knowledge of the impact of air pollution on human beings caused by brick kilns. However, they held the belief that it could harm local crops due to the lack of education among the majority of them. They held the rather unusual belief that air pollution is beneficial for plants. The lack of awareness regarding the impact of air pollution on agriculture in the affected areas is disheartening, considering that the findings were made over a decade ago. The owners of the brick kilns were employing outdated techniques for brick firing and were utilizing any available material as fuel, resulting in a significant increase in air pollution (Figure 4). In addition, they had no knowledge of any alternative fuel other than natural gas, which is prohibitively costly for commercial purposes.

Fig 4: Domestic waste used for brick firing that includes used shoes, plastic bottles plates etc at the brick kiln fields of Peshawar.

The latest survey clearly indicates that there has been no improvement in the environmental pollution caused by brick kilns in Peshawar. The brick kiln owners lacked knowledge about any renewable technology capable of mitigating HF pollution, such as advanced filtration and scrubbing technology. These technologies capture air pollutants before they are released into the atmosphere and can be used to upgrade older kilns to more efficient and modern designs. Examples of such designs include vertical shaft brick kilns or improved zigzag kilns, which produce lower emissions.

Status of Monitoring and Maintenance

According to the latest survey, it was noted that 95% of the brick kilns are neglecting maintenance due to the exorbitant expenses involved. In 2012, a study was conducted to measure the levels of HF pollutant and its effects on crops in the area[10]. However, aside from the study conducted by Saleem[13] on the sensitivity of tomatoes to fluoride pollution from brick kilns, no additional measurements or research has been conducted. In Pakistan, the monitoring of brick kilns is subject to rules and regulations set by the Environmental Protection Agency of The KP Province (EPA). The EPA is responsible for enforcing and regulating environmental laws in the province, as outlined in the 1997 Act for Environmental Protection. The Act pertains to the regulation and surveillance of air, noise, and water pollution. Sections 11, 13, and 14 of the law specifically address air pollution and impose a maximum penalty of PKR 1 million. In addition, there is an extra penalty of PKR 100,000 for repeated violations of environmental offenses[7].

Buffer zones and Protective barriers

In the area, there were numerous towering Poplar trees primarily cultivated for timber and agro-forestry purposes, rather than being utilized as protective barriers for HF emissions. This practice has been continuous for centuries in the KP province[14]. Nevertheless, this method proves ineffective in safeguarding the crops and orchards from the harmful emissions of brick kilns due to the presence of numerous brick kilns within a 15km^2 radius, with chimneys that exceed the height of the poplar trees. Thus, it is an impractical solution for mitigating air pollution caused by brick kilns.

Crop Management and Agricultural Practices

Multiple cultivars of wheat, tomato, and potatoes were documented during the survey. The majority of them were prone to F injury and toxicity. The issue arose from the lack of knowledge among the individuals regarding any crop varieties that possessed resistance to F in the brick kiln areas. Furthermore, no studies were conducted to identify resistant varieties of major cash crops such as wheat, maize, and rice. Ahmad[10,11] proposed that it is necessary to evaluate the tolerance of new crop varieties to air pollution, particularly to O_3 and HF, which can cause a significant decrease in crop yield of 40-60% in Pakistan[15]. Hence, it is crucial to implement a management strategy that can effectively identify crop varieties that are resistant to HF, thereby mitigating its impact on crops. The farmers were hesitant to adopt cover/green protection for their crops due to the impracticality of covering their extensive fields, which would require significant funding. The optimal course of action is to determine the timetables and sites of plant operations in order to steer clear of periods when there are high levels of HF emissions or when the plants are located near the brick kilns.

Educating community and Brick Kiln Workers

The majority of the local community and brick kiln workers residing in the vicinity of the brick kiln area were uninformed about the detrimental effects it can have on vegetation. Nevertheless, they were greatly disturbed by the emission and its impact on their health. Rafiq & Khan[7] found that the concentration of PM10 near brick kilns in Peshawar was significantly higher (415ug/m^3) compared to control sites (180 ug/m^3). By reducing PM10 levels to the threshold level, it is estimated that an annual savings of PKR 3315 per person can be achieved solely through the cost of mitigation. The annual welfare gains from reducing air pollution to the threshold level in Peshawar district through mitigation costs amount to PKR 6692.985 million. The cost may have increased further as a result of the rise in brick kilns and air pollution. A new study is required to accurately calculate the cost of health effects caused by pollution from brick kilns.

Policy and Regulation for Brick Kiln Operation

There is comprehensive environmental policy govern by EPA in the province. However, from the latest survey there was little or no impact from the policy devised by the local government. The brick kiln owners and local farmers were asking for tax rebates and incentives before going to adaptation or mitigation process to reduce the air pollution.

CONCLUSION AND RECOMMENDATIONS

Developing sustainability strategies to address the impact of hydrogen fluoride emissions, from brick kilns in South Asia requires the application of management science principles. These strategies should encompass

mitigation efforts, technology adoption, policy development and community engagement.

Innovations in Technology Adoption

Cleaner Kiln Technologies

-Promoting the use of Vertical Shaft Brick Kiln (VSBK) technology is crucial for its energy efficiency and reduced emissions compared to kilns. VSBK operates on a shaft principle that enhances heat utilization leading to coal consumption and emissions.

-Transitioning to Hybrid Hoffman Kiln (HHK) technology combines Hoffman kiln features with techniques enabling precise regulation of air flow and temperature control for significant emission reductions.

-Converting fixed chimney bull's trench kilns into zigzag kilns is a cost approach, to improving airflow patterns within the kiln. This modification enhances coal combustion efficiency. Reduces emissions, including hydrogen fluoride pollutants.

Fluoride Removal Solutions

Scrubbers: Install scrubbers, in kilns to trap emissions before they are released into the air. Different solvents can be used in scrubbers to capture or neutralize hydrogen fluoride.

Bag Filters:Use baghouse filters to catch particles and gases. These filters can be modified to capture emissions by treating them with substances that react with fluoride.

Financial Support and Incentives

-Subsidies and Loans: Offer subsidies or low interest loans to kiln owners for covering the expenses of upgrading technologies. This financial assistance plays a role in promoting the adoption of methods.

-Tax Benefits: Provide tax incentives or other financial rewards to companies investing in technologies or achieving reductions, in emissions.

Building Skills and Training

-Training Programs; Organize workshops and training sessions for kiln operators and workers to learn about technologies and how to maintain emission control systems effectively.

-Support Services; Create support centers or hotlines where kiln operators can receive expert guidance, on troubleshooting technology issues and carrying out maintenance tasks.

Establishing Clear Emission Regulations

-Specific Regulations for Hydrogen Fluoride; Set stringent emission regulations for hydrogen fluoride that align with health and environmental safety standards. These regulations should take into account conditions and the potential health effects on nearby communities.

-Kiln Performance Standards; Enforce performance standards, for both existing kilns to ensure they comply with guidelines. This may involve requiring the use of technologies or upgrading kilns to reduce emissions.

Environmental Regulations

Creating a Comprehensive Legal Framework; Drafting laws that specifically target emissions, from industrial sources like brick kilns. These laws should encompass all aspects of kiln operations from construction to dismantling.

Implementation of Permit System; Introducing a system where kilns can operate with permits granted based on meeting environmental standards. Renewal of permits should be subject to adherence to hydrogen fluoride emission regulations.

By employing these approaches stakeholders can effectively. Decrease hydrogen fluoride emissions promoting sustainable practices in brick manufacturing in suburban regions of South Asia. These strategies not safeguard flora but also contribute to wider environmental and public health advantages.

Recent research has revealed a rise in HF and other pollutants emitted by brick kilns raising agricultural issues. To ensure practices it is crucial to integrate technologies and use ecofriendly materials like wheat straw as additives in brick making. This method aims at reducing air pollution emissions. It is vital to discourage the use of fuels derived from household waste containing items, like leather shoes and plastic materials.

A fresh study is needed to look into how HF pollution affects crops on farms given the absence of a limit, for HF, in the nation. This absence of rules could endanger the country's food stability with numerous brick kilns situated on farmlands.

ACKNOWLEDGMENT

The authors appreciate the support from the Researchers Supporting Project number (RSPD2024R997), King Saud University, Riyadh, Saudi Arabia.

CONFLICT OF INTERESTS

None

REFERENCES

[1] Vithanage, M., & Bhattacharya, P. (2015). Fluoride in the environment: sources, distribution and defluoridation. Environmental Chemistry Letters, 13, 131-147.

[2] Cai, H., Dong, Y., Peng, C., Li, Y., Xu, W., Li, D., & Wan, X. (2017). Fluoride-induced responses in the chlorophyll content and the antioxidant system in tea leaves (Camellia sinensis). Fluoride, 50(1), 59.

[3] Feng, Y. W., Ogura, N., Feng, Z. W., Zhang, F. Z., & Shimizu, H. (2003). The concentrations and sources of fluoride in atmospheric depositions in Beijing, China. Water, Air, and Soil Pollution, 145, 95-107.

[4] Wang, M., Li, X., He, W. Y., Li, J. X., Zhu, Y. Y., Liao, Y. L., ... & Yang, X. E. (2019). Distribution, health risk assessment, and anthropogenic sources of fluoride in farmland soils in phosphate industrial area, southwest China. Environmental Pollution, 249, 423-433.

[5] Choudhary, S., Rani, M., Devika, O. S., Patra, A., Singh, R. K., & Prasad, S. K. (2019). Impact of fluoride on agriculture: A review on it's sources, toxicity in plants and mitigation strategies. Int J Chem Stud, 7(2), 1675-1680.

[6] Rizzu, M., Tanda, A., Cappai, C., Roggero, P. P., & Seddaiu, G. (2021). Impacts of soil and water fluoride contamination on the safety and productivity of food and feed crops: A systematic review. Science of the Total Environment, 787, 147650.

[7] Rafiq, M., & Khan, M. (2014). The health costs of the brick kilns emissions in Peshawar: A policy analysis. Current World Environment, 9(3), 591-601.

[8] Petersen, P. E., & Lennon, M. A. (2004). Effective use of fluorides for the prevention of dental caries in the 21st century: the WHO approach. Community dentistry and oral epidemiology, 32(5), 319-321.

[9] World Health Organization. (2009). Bromide in drinking-water: Background document for development of WHO Guidelines for Drinking-water Quality (No. WHO/HSE/WSH/09.01/6). World Health Organization.

[10] Ahmad MN, LJLVD Berg, HU Shah, T Masood, P Büker, L Emberson and M Ashmore. 2012. Hydrogen fluoride damage to fruit trees in the vicinity of brick kiln factories in Asia: an unrecognised environmental problem? Environmental Pollution, 162 (1): 319-324.

[11] Ahmad MN, SS Ahmad, A Zia, MS Iqbal, HU Shah, AA Mian, RU Shah (2014) Hydrogen fluoride effects on local mung bean and maize cereal crops from peri-urban brick kilns in South Asia. Fluoride 47(4): 315-319.

[12] Wahid A, SS Ahmad, MN Ahmad, B Khaliq, M Nawaz, S Qasim and RU Shah. 2014. Assessing the effects of hydrogen fluoride on mango (mangifera indica l.) in the vicinity of brick kiln field of Southern Pakistan. Fluoride 47(4): 307-314.

[13] Saleem, M, MN Ahmad, B Ahmed Khan, A Zia, SS Ahmad, HU Shah, NA Khan IM Qazi (2015) Effects of soil fluoride on the growth and quality of two tomato varieties grown in Peshawar. Fluoride 48 (2) 174-178.

[14] Ali, C. A., Khan, A., & Hakim Shah, H. (2011). Agroforestry in Khyber Pakhtunkhwa: current situation and future prospects. Pak J Forest, 61(1), 1-11.

[15] Wahid, A. (2006). Influence of atmospheric pollutants on agriculture in developing countries: a case study with three new wheat varieties in Pakistan. Science of the Total Environment, 371(1-3), 304-313.