Fluoride 2019 Feb 10. www.fluorideresearch.org/epub/files/023.pdf [Epub ahead of print]

ASSESSMENT OF FLUORIDE DAMAGE TO WHEAT (*TRITICUM AESTIVUM*) CULTIVATED NEAR BRICK KILNS IN THE RAWALPINDI DISTRICT, PAKISTAN

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ABSTRACT: The production of bricks by baking in kilns has occurred since ancient times in South Asia. The growth of modern urbanization has resulted in more kilns being required for brick production. Kilns are a source of fluoride emissions which cause damage to plants growing nearby. The aim of the present study was to study the effect of fluoride emissions from brick kilns on winter wheat being cultivated in the surrounding fields. The study (i) assessed the damage caused by fluoride to the wheat plants, (ii) determined the concentration levels of fluoride in the leaves, and (iii) measured the plant health index. The fluoride concentration was measured with a fluoride ion meter and the plant health was assessed using a raster calculator in ArcGIS 10.2v. The results revealed that great damage occurred, with visible foliar injury, to the wheat plants located within 100 m of the brick kilns.

Keywords: Brick kilns; Fluoride; Foliar Injury; NDVI; Plant health index; Wheat.

INTRODUCTION

Pakistan is an agriculturally based country in South Asia where the major cultivated crop is the staple food of wheat. The Punjab province makes a major contribution to wheat production. However, an increase in the population in northern Punjab is causing an expansion of the urban areas. The increasing urban areas are encroaching on the peripheral rural areas in the Punjab and land cultivation is declining. The soil of the Punjab is not only suitable for crop cultivation but is also used for making bricks.[1] Brick baking has occurred for four thousand years in this region.[2] There are a number of poorly regulated brick kilns in different areas and no accurate record has been found of the number of operational kilns in any province of Pakistan.[3]

Most kilns are located in rural areas surrounded by fields in which different crops are cultivated by the local communities. Kilns have been identified as a source of fluoride pollution which ultimately affects the plants growing nearby. Fluoride compounds affect plant growth and cause foliar necrosis.[4,5]

The fluoride emissions from the kilns are in a gaseous form and enter the plant leaves through the stomata and dissolve in the apoplast. In the plant, the fluoride compounds alter the photosynthetic process and ultimately cause leaf margin necrosis and growth reduction. The impact of fluoride pollution on crops has been documented by various researchers world wide.[6,7, 8]

Fluoride is found naturally in soil in concentrations of up to 300 ppm. For some plants, fluoride is hazardous even when found at concentration levels that are 10 to 1,000 times lower than that of other pollutants.[9] Hydrogen fluoride (HF) has been identified as a source of damage to plants such as beans, tea, spinach, and mango.[10-15]

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The development of the Geographical Information System (GIS) technique has made it possible to study different geographical areas on a large scale and to provide critical information for researchers for predicting the consequences of different changes. The raster calculator is available for measuring and assessing the different environmental attributes. Moreover, plant health can be monitored by evaluating the vegetation index, which gives values between –1 and +1 which reflect the presence of poor or good health (–1 to <0.5 =poor plant health; >0.5 to +1=good plant health).[8]

Pakistan's GDP is dependent upon the major cultivated crops. Hence, it is necessary to understand the threats to crop cultivation from kilns and to manage the cultivated land in the vicinity of kilns.

The objectives of the present study were to assess the damage caused by fluoride to wheat plants, to determine the concentration levels of fluoride in the leaves, and to measure the plant health index.

METHODOLOGY

Study area: The study area was the Rawalpindi district which is located in the north of the Punjab province of Pakistan at 33.4095ºN and 72.9933ºE at an elevation of 2,790 m. The Rawalpindi district has a total of seven administrative tehsils but only three tehsils (Rawalpindi, Gujarkhan, and Kallar Sayedan) were selected for the present study on the basis of the existing agricultural fields in the surroundings of operational brick kilns at various distances, i.e., 100 m and 500 m. A total of 375 brick kilns were identified in these three tehsils of the Rawalpindi district (Figure 1).

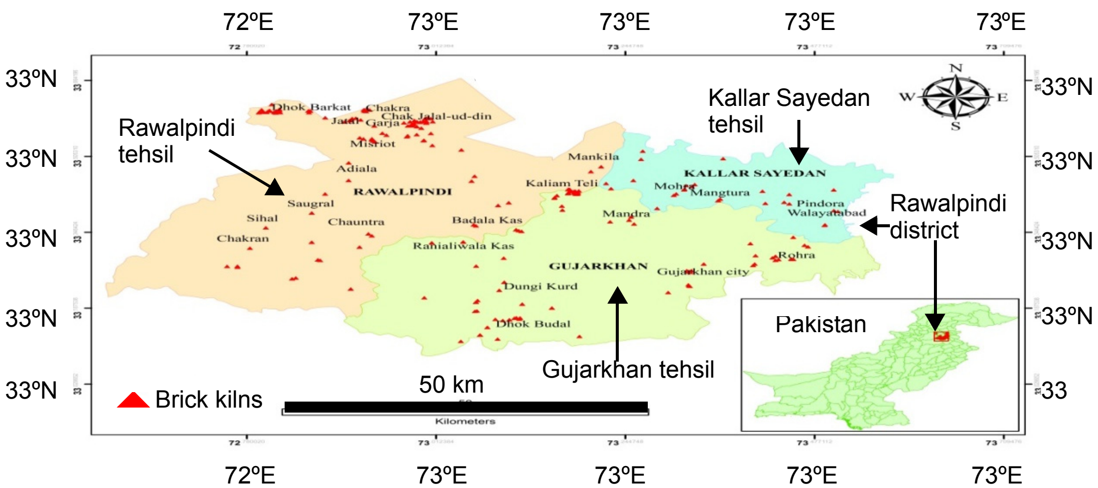

Figure 1. The study area showing the sampling sites in the three tehsils of Rawalpindi, Gujarkhan, and Kallar Sayedan in the Rawalpindi district. The red triangles show the sites of the brick kilns.

Assessment of the visible leaf injury in the wheat crop: The leaf injury was identified as necrosis of the leaf margins. The injury quantification was made during the month of March in the years 2015, 2016, and 2017. The percentage injury rate was measured on the basis of the frequency of damaged leaves (Equation 1).[16]

$$\text{Percentage leaf injury rate (\%)} = \frac{\text{Total number of infected leaves}}{\text{Total number of leaves observed}} \times 100 \quad \text{... Equation 1}$$

Sample collection: Leaf samples were collected randomly using the W sampling design method. Six affected leaves from each point were collected and made into a composite sample for every selected field. The selected leaves were fully mature and of a similar size. These leaves were later sealed in plastic sampling bags and labelled. The samples were then transferred to the laboratory of the Fatima Jinnah Women University, Rawalpindi, for analysis.

Fluoride concentration level: Initially, the weight of all the leaf samples was measured, and they were then dried at 70ºC for 48 hr and ground into a fine powder. The fluoride analysis was done by the acid digestion method.[8] For the measurement, a 10 mL sample extract was mixed with TISAB III and then measured using a fluoride sensitive electrode ion meter.

Plant health index: The plant health index was measured using a raster calculator to find the Normalized Difference Vegetation Index on ARCGIS 10.2 v. LANDSAT satellite images for the years 2015, 2016, and 2017 were obtained from the USGS Glovis. The particular month of March was selected to observe and calculate the health of the wheat plants when they were fully grown and showed the maximum effect of pollutants on the leaves. The NDVI value ranged from –1 to +1. A value above 0.5 up to 1 indicates good plant health while a value below 0.5 down to –1 indicates poor plant health. The NDVI was calculated using following equation (Equation 2).[17]

$$\text{Normalized difference vegetation index (NDVI)} = \frac{\text{NIR} - \text{Red}}{\text{NIR} + \text{Red}} \qquad \text{... Equation 2}$$

Climatic data: The climatic data including the temperature, precipitation, and wind speed and direction were retrieved from the NETCDF file format using GRADS and MS Excel. These data were used to analyze the effect of different climatic parameters on the concentration level of the fluoride emitted from the kilns and the resulting damage.

RESULTS AND DISCUSSION

Leaf injury was observed in the form of necrosis on the margins and burning of the tip of the leaves during the month of March in the years 2015, 2016, and 2017 when the leaves were fully mature. During the year 2015, less visible leaf injury was observed overall in the fields of wheat plants except for one area of tehsil Rawalpindi. Visible leaf injury to wheat plant was high in the area of Chakran located in the West of Rawalpindi. However, no injury was observed in the fields of Dhok Akbar which was the control site of the present study (Figure 2). Very little leaf injury was observed in the fields of tehsil Kallar Sayedan (Figure 3). In tehsil Gujarkhan little visible leaf injury was observed in the fields located in Rohra and in the main Gujarkhan city areas (Figure 4). Moreover, most foliar damage was found within 100 m distance from the brick kilns. The findings of the present study were similar to those of a study conducted in the Pothar region of Rawalpindi.[8,11,18]

The fluoride concentration in the samples of the wheat plant leaves was measured through chemical analysis, which indicated varied concentrations occurred in different places and years. In tehsil Rawalpindi, the average fluoride concentration found in the samples was 1.524, 2.807, and 3.329 ppm in the years 2015, 2016, and 2017 respectively (Figure 5).

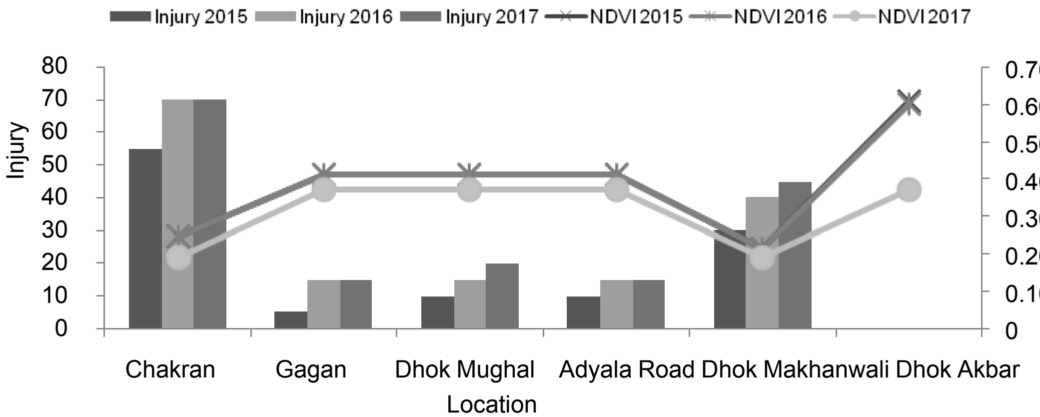

Figure 2. Visible leaf injury and NDVI in tehsil Rawalpindi.

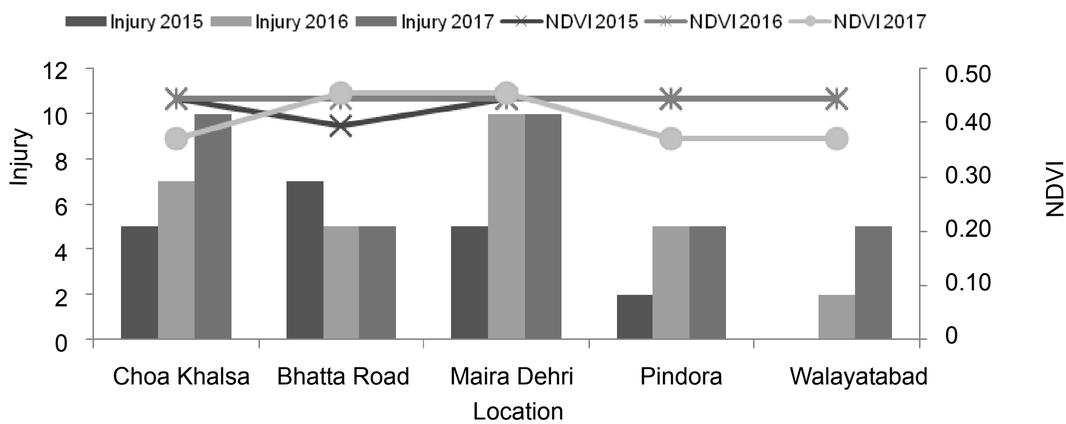

Figure 3. Visible leaf injury and NDVI in tehsil Kallar Sayedan.

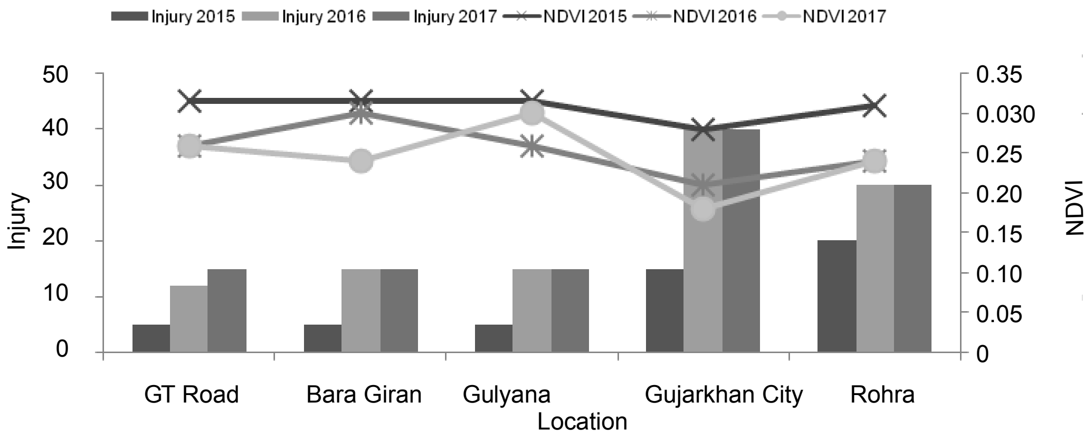

Figure 4. Visible leaf injury and NDVI in tehsil Gujarkhan.

For comparison, the average concentrations measured in the samples collected from Gujarkhan tehsil was 1.47, 2.03 and 3.289 ppm in the years 2015, 2016, 2017. The sample analysis from the Kallar Sayedan tehsil revealed comparatively lower fluoride concentrations in the samples with the average concentrations for the years 2015, 2016, and 2017 being 0.45, 0.823 and 1.34 ppm.

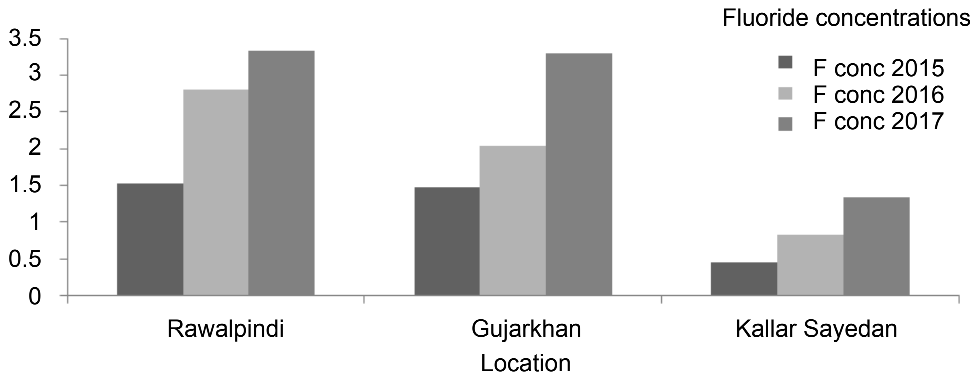

Figure 5. Fluoride concentration (ppm) in district Rawalpindi.

The normalized difference vegetation index revealed the health of the wheat plants cultivated in the fields. Figure 2 shows that the NDVI of the wheat plants ranged from 0.21–0.611 in Rawalpindi during the year 2015. The fields in Chakran and Dhok Makhanwali were the most affected and showed a significantly lower NDVI value of 0.21. This indicated that there was poor plant health in those places while in Dhok Akbar, the control area, a significantly higher NDVI value was calculated for the year 2015 of 0.61. Similar results were observed for the year 2016. In contrast, for Chakran and Dhok Makhanwali, for the year 2017, remarkably lower NDVI values were calculated ranging from 0.19–0.37.

Figure 3 shows the values of the NDVI for the wheat plants cultivated in the Kallar Sayedan tehsil for the years 2015, 2016, and 2017, were 0.39–0.44, 0.44, and 0.37–0.45, respectively.

Tehsil Gujarkhan showed varied NDVI values for the three years. In 2015, the plant leaves showed a NDVI range from 0.28–0.31, while in the years 2016 and 2017 there was significantly poorer health in the plants in the fields of Rohra (NDVI 0.24) and Gujarkhan city (NDVI 0.21, 0.18) (Figure 4). However, the fields surrounding the kilns in other places (GT Road, Bara Giran, and Gulyana) also showed lower NDVI values for the years 2016 and 2017 which indicated that the wheat plants were in poor health in those years.

Climate, including the precipitation rate, temperature, and wind has a very significant role in the growth of plants, and the emission, distribution, and effects of pollution on nearby plants. It was a common observation in all three study years that the brick kilns did not work on the rainy days and were only operational on sunny days. In district Rawalpindi during the surveys in the year 2015, it was observed that the brick kilns were often non-operational during the rainy months, especially in the February and March (Figures 6–8).

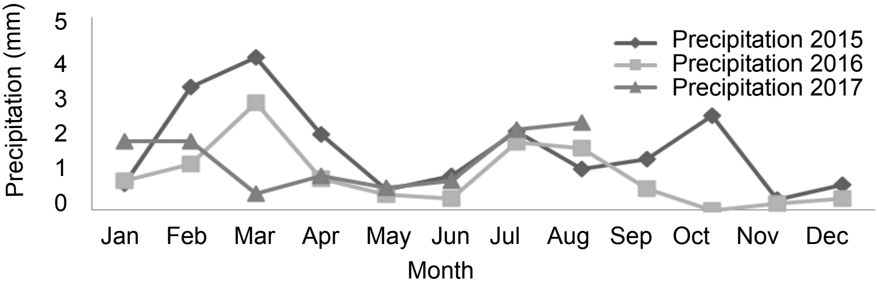

Figure 6. Average monthly precipitation in tehsil Rawalpindi in 2015–2017.

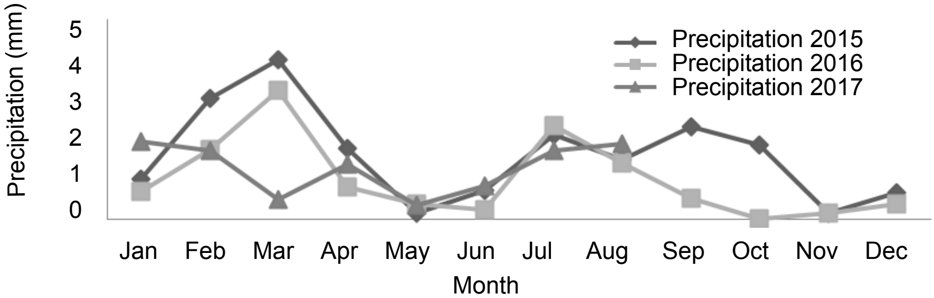

Figure 7. Average monthly precipitation in tehsil Kallar Sayedan in 2015–2017.

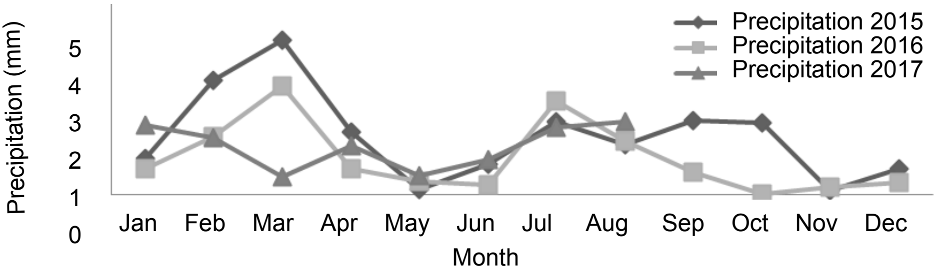

Figure 8. Average monthly precipitation in tehsil Gujarkhan in 2015–2017.

In the year 2016, less precipitation occurred in the month of February but March was a rainy month so kilns were operational for some weeks in February. The kilns operated regularly in the year 2017 when significantly less precipitation occurred. The wind blows from west to northeast during the months of December to April in district Rawalpindi.

CONCLUSION

On the basis of our results it can be concluded that the fluoride emissions from brick kilns has a great impact on the health and growth of the plants in the surrounding areas. Although a number of emission control technologies at the industrial level have been introduced by the Pakistan Environmental Protection Agency, the brick baking industry is still a poorly regulated economic sector. Our study findings revealed that the kilns in district Rawalpindi were non-operational on rainy days. In the year 2015, less foliar injury and good plant health were recorded because of the high precipitation in the months of February and March. The highest concentration of fluoride, percentage of foliar injury, and poor plant health were observed in the years 2016 and 2017 because of the lower precipitation during winter. More foliar damage was found within 100 m from the kiln areas. The present study can be used as a model for quantifying the crop damage caused by fluoride pollution.

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