PARTICULATE AIRBORNE FLUORIDE FROM AN ALUMINIUM PRODUCTION PLANT IN ARAK, IRAN

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SUMMARY: The total fluoride (F) content in particulate matter in the air at 20 sampling sites in Arak city, which has the largest aluminium production plant in Iran, was determined by ion chromatography/conductivity. Total F particulate content for a 3-hr period was measured in triplicate every 10 days at each site at the same time in July 2008. The maximum F content was 390.1 μg/m^3 and the minimum was 3.2 μg/m^3. The mean level was 73.43 μg/m^3.

Keywords: Airborne fluoride; Aluminium smelter; Arak, Iran; Particulate fluoride.

INTRODUCTION

Fluoride (F) in both gaseous and particulate forms is emitted into the air by different types of coal-burning and industrial operations such as power generation and the production/manufacture of aluminium (Al), brick, glass, plastics, steel, fertilizers, and ceramics.[1,2] The main sources of F intake by humans are usually water and food, but very low levels of F are usually present in air. In most non-industrial areas an airborne F content of less than 1 μg/m^3 is normal,[3] but in industrial areas occupational and public exposure of F air may become important.[1,2]

Most studies of F emissions are on gaseous forms (HF and SiF_4) rather than on particulate F. In the air around Al smelters, the diameter of particulate airborne F varies from 0.1 to 10 μm, which is capable of entering the lungs.[4] Since such particulate F can be stable in air and not readily hydrolyzed,[3] its respiratory toxicity[5,6] may not always be evident. In Iran there have been a number of studies concerning the F content of food and especially water,[7-13] but there appear to be none about F concentrations in the air. Consequently, the present study was undertaken to determine the airborne particulate F levels in city of Arak, which has the largest Al production plant in Iran.

MATERIALS AND METHODS

This study was conducted in July 2008 in Arak city in Markazi Province (Figure 1). Arak has a population of 600,000 inhabitants; the climate is warm and dry in summer, and cold and humid in winter. Arak is located southwest of Tehran between mountain ranges on the south, west, and southwest. With an elevation of 1700 m above sea level, Arak in July usually has a fairly stable air movement. As shown in Figure 1, an aluminium (Al) production plant, the largest in Iran, is located near the southeastern edge of Arak.

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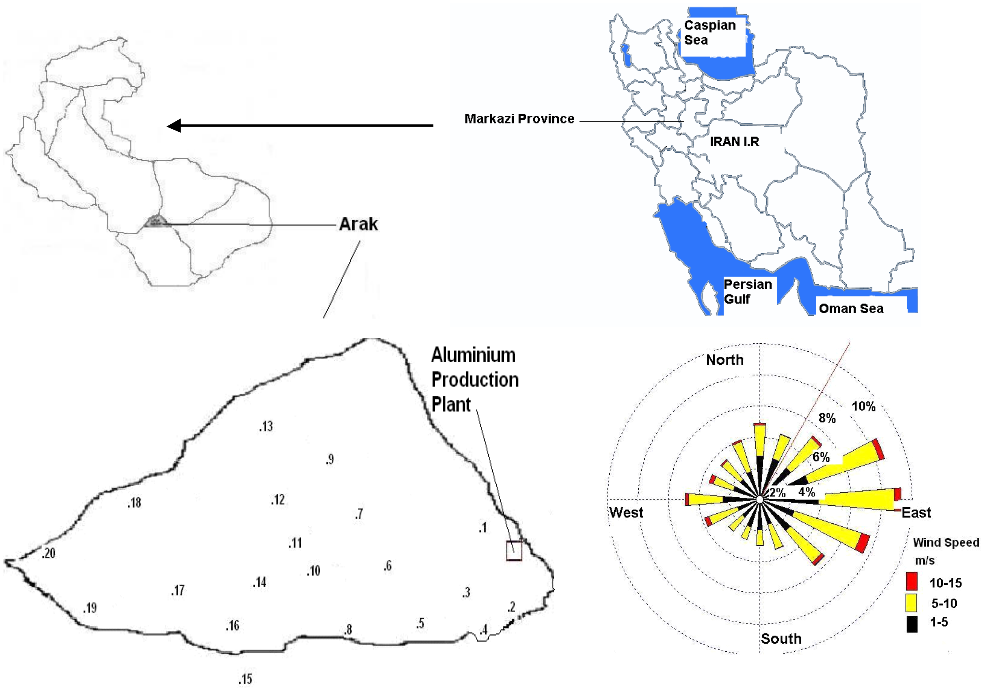

Figure 1. Location of Arak in Iran showing sampling sites and wind-rose data in July 2008.

In July the wind speed is generally fairly low, and the wind direction is predominantly from the east and eastnortheast. Twenty sites or points in Arak at different distances from the Al plant were selected for sampling. The ground elevations of these points are nearly the same, and the height and diameter of the factory stack are 60 and 5 m, respectively. The NIOSH 7906 method[14] was used for sampling and determination of the total amount of F in the particulate matter by the ion chromatography/conductivity method. Total F particulate content for a 3-hr sampling period was measured in triplicate every 10 days at each sampling point at the same time in July 2008.

RESULTS AND DISCUSSION

In the Table are shown the total particulate F content in the air and distance of the sampling points from the Al plant. The mean concentration of total particulate F in the air varied widely from 5.5 to 336.1 μg/m^3 with a mean level of 73.43 μg/m^3. For comparison, in a related study in British Columbia, Canada, the airborne F level in a high exposure area was 280 μg/m^3 as particulate F.[15] On Cornwall Island on the St. Lawrence River, at a distance of 1.5 km from an Al plant, the 12-hour maximum particulate F content was 5.53 μg/m^3 and the average was 0.31 μg/m^3.[16]

Table. Total particulate F content of samples at selected points and their distance from the aluminium production plant (maximum value of F content is expressed as bold italic; minimum values as bold underlined)

Number of sampling point	Distance from aluminium production plant (km)	Mean 3-hr F-content in the air (µg/m^3)	Max 3-hr F-content in the air (µg/m^3)	Min 3-hr F-content in the air (µg/m^3)
1	2	16.7	20.86	10.4
2	2.1	47.2	60.2	31.1
3	2.6	233.3	298.9	190.3
4	2.8	19.4	30.4	10.15
5	3.8	308.3	370.8	250.45
6	4.1	55.6	71.3	29.9
7	4.4	36.1	50.2	19.75
8	5.4	8.3	14.1	4.9
9	5.5	13.9	20.7	4.8
10	6	***336.1***	***390.1***	***269.66***
11	6.2	27.2	39.1	13.12
12	6.4	11.1	21.3	5.2
13	6.6	16.7	28.4	9.15
14	6.7	77.78	91.34	50.9
15	7.9	**5.5**	**8.2**	**3.2**
16	8	175	215.1	152
17	9.5	25	32.7	14.6
18	9.9	22.2	29.1	15.9
19	11.5	19.4	32.65	9.72
20	13	13.9	19.1	6.7
Total mean		73.43		

The World Health Organization has reported 100–500 µg F/m^3 in air near a phosphate manufacturing facility.[17] Differing results are reported for the F content in the air, soil, and vegetation depending on air conditions and the distance from an Al production plant.[18-21] In China the F content of unventilated indoor air ranged from 3.2 µg/m^3 to 56.8 µg/m^3 in three different areas.[22] In Ontario, Canada, the ambient air quality criteria for total F (gaseous and particulate) are 1.72, 8.6, and 0.69 µg/m^3, respectively, for ambient 24-hr value, half-hour point of impingement standard, and 30-day ambient air quality criterion expressed during the growing season.[21] For Victoria in British Columbia of Canada, the maximum average design criteria for F in 24 hours, 7 days, and 90 days are 2.9, 1.7, and 0.5 µg/m^3, respectively.[23] The basis of these values is to protect against adverse effects on vegetation by minimizing F accumulation, since certain types of vegetation are more sensitive to F exposure than humans.[23-25] In Arak there is evidence of damage to vegetation that may be related to elevated levels of F in air around the Al production plant (Figure 2). As expected, these adverse effects on plants are less noticeable in the western part of Arak at greater distances from the Al production facility.

Figure 2. Leaf-edge necrosis in *Morus alba* in a regional park near the aluminium production plant in Arak.

According to another reference,[26] the 1-hour exposure level of F to protect against respiratory irritation is near 0.6 mg/m^3, and the content to protect against severe irritation from a once-in-a-lifetime exposure is near 1.6 mg/m^3.[26] Information from different sources indicates that long-term exposure of humans (children and workers) to 0.1–0.5 mg F/m^3 leads to impairment of respiratory function and skeletal fluorosis.[26] However, the available data does not permit the derivation of an air quality guideline value for fluoride(s).[26] In other studies in other countries, the occurrence of environmental F contamination by industrial activities, mainly from Al smelters, has shown adverse effects on vegetation and animals and lesser effects on human.[27]

In relation to air quality criteria, the particulate F levels in the air in Arak are high, but as yet there are no data concerning health effects related to airborne F in the city. The existing mountains to the south, west, and southwest, 24-hr and continuous production of Al in the smelter, low stack height, stability of air, and a low wind speed in Arak are probably the most important reasons for the high F content in the air. Consequently, it is critically important that more efficient devices be installed in the Al plant to control its emission of air pollutants, especially F, both gaseous and particulate.

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