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NEIGHBORHOOD FLUOROSIS IN WESTERN INDIA
PART II: POPULATION STUDY

by

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SUMMARY: The present study covers 15 villages and 3 urban residential areas within a radius of 3500 meters from the fluoride-processing industry (manufacturing a refrigeration gas, i.e. Freon) on the west coast of India, north of Bombay. In a population study of 7059 persons, health complaints, fluorotic dental changes, fluoride excretion in spot urine samples and x-ray of the forearm were used to assess the effect of industry on human health: 17.02% of persons complained of adverse effects to health. Complaints per sick person averaged 1.31%. The prevalence of dental changes (23.58%) was highest in the 7-14-year-

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old group. Mean fluoride level of 395 spot urine samples was 1.94 ppm. Radiological evidence of fluorosis, usually only seen in older individuals, was observed in 9.5%.

KEY WORDS: Fluoride processing industry; Fluorotic dental changes; Health complaints; Neighborhood fluorosis; Radiological changes; Urine analysis.

Introduction

Industrial and neighborhood fluorosis, the effect of fluoride-emitting industry on human health, has been described in detail in the literature (1-7). In India, the fluoride-processing industry manufacturing a refrigeration gas, the only one of its kind, was established on the west coast north of Bombay in 1966. Residents of the surrounding villages complained about an unknown illness affecting health and milk output of their cattle.

Preliminary investigations revealed fluorosis. Cattle would be affected first because they graze on grass and forage contaminated by the fluoride gas.

The present study was carried out to learn the extent of the problem of neighborhood fluorosis and to obtain baseline information for future study.

Population: The total population of these villages and residential areas (1971 census) was 19,419 (Table 1). The rural people are engaged in agriculture and raise cattle, mainly buffalos and cows. Fodder is grown locally for cattle and land-owning families who comprise about 40% of the population, and own an average of 4-6 head of cattle. Landless laborers, about 40% of the population, are very poor. They live in huts and own no cattle. The remaining 20% of the village population is engaged in commerce, transport and work in small shops. The village population, which has been settled for more than 10 years, consumes local crops and vegetables mainly jowar, rice, sugar cane, bananas and vegetables. The urban population, is almost entirely industrial; a large proportion of the people are migrants who have been living there for 1-10 years.

Material and Methods

In a house to house survey, carried out in the study area, whatever family members were available at the time were clinically examined for dental changes, changes in bone and joint and or signs of spinal compression. Health complaints by the subjects were likewise recorded as well as all basic epidemiological information such as age, sex, etc.

For good coverage, attempts were made to examine the children of all primary and secondary schools in the study area. Since in children, apart from dental changes, the manifestations of ill-effects from high fluoride intake (1) may not be recognized as fluorosis, much emphasis was placed on examining teeth for dental fluorotic changes. For the same reasons the

children did not receive radiological examinations nor was urinary fluoride measured.

Spot urine samples of randomly selected clinically examined individuals were collected in plastic bottles and preserved by addition of thymol until analyzed. Considering the feasibility, it was planned to take x-rays of right forearm, A.P. view, along with the standard aluminum wedge to study calcification of interosseous membrane and sclerosis of bones. X-rays in at least 50 examined adults in each village were carried out.

Estimation of fluoride in drinking water and in spot urine samples was done by using the Orion ion specific electrode and the results were expressed in ppm. A.P. view x-ray of the forearm and spot urine samples according to direction and distance from the industry are shown in Table 1.

Table 1

Population, Urine (Spot Samples) for F⁻ Estimation and X-ray of Forearm

	Total	Direction in relation to industry				Distance from industry (meters)		
		NE	NW	SE	SW	II (500-1500)	III (1500-2500)	IV (2500-3500)
No. of persons clinically examined	7059	2337	1022	1652	2048	2774	2119	2166
14 yrs. of age	3620	1133	545	730	1212	1531	1089	1000
14 yrs. of age	3439	1204	477	922	836	1243	1030	1166
Spot urine samples	395	172	58	122	43	99	156	140
X-ray of forearm	411	149	38	145	79	147	148	116

Table 2

Symptomatology in Neighborhood Fluorosis

Complaints	Number	Prevalence rate of complaints (%)
Spinal pain	739	10.46
Joint pain	639	9.05
Myalgia	129	1.82
Parasthesis	11	0.15
Headache	6	0.08
Nasal and conjunctival congestion and secretion	4	0.05
Asthma	18	0.25
Chest pain	27	0.38
Total	1573	22.23

Total persons examined - 7059; Persons having health complaints - 1202 (17.02%); Total number of complaints - 1573 (22.23%); Average number of complaints per sick person - 1.31

A. Overall Observations: Of 7059 individuals examined, 1202 (17.02%) had one or more health complaints. Prevalence rates of various complaints of the people are shown in Table 2. In 1665 (23.58%), various grades of dental changes suggestive of fluorosis with their prevalence rates are shown in Table 3. In the 7-14 year old group, prevalence of dental changes was significantly higher (41.9%) than in children 0-7 years of age (18.8%) ($d = 20.18, P < 0.001$). (Table 4). The sexes were equally affected

The mean urinary fluoride value of 395 spot samples was 1.94

Table 3

Dental changes	Number of persons	Prevalence rate (%)
Mottling	479	6.79
Chalky white	668	9.46
Pitting	126	1.78
Mottling and chalky white	202	2.86
Chalky white and pitting	118	1.67
Mottling and pitting	58	0.82
Mottling, chalky white and pitting	14	0.20
Total	1665	23.58

Total number examined - 7059

This distribution was statistically significant ($X^2 = 46.916$, d.f. = 3, $P < 0.001$).

The prevalence of fluorotic dental changes was 24.69% (NE), 23.48% (NW), 20.03% (SE) and 25.13% (SW) with a statistically significant distribution at 0.001 level ($X^2 = 15.63$, d.f. = 3). When different regions were compared, the difference between NE and SE was significant ($d = 3.40$, $P < 0.02$), NW and SE ($d = 2.01$, $P < 0.05$); SE and SW ($d = 3.61$, $P < 0.001$).

Mean urinary fluoride

levels of spot samples in regions, NE, NW, SE, and SW were 2.18 ppm, 2.12 ppm, 1.54 ppm, and 1.91 ppm respectively. Only the values between the NE and SE regions differed significantly ($Z = 3.21$, $P < 0.01$). Similarly the proportion of urine samples, higher in fluoride than 4.5 ppm, was also significantly higher in the NE (11.04%) than in the SE (4.91%) ($d = 1.98$, $P < 0.05$).

The proportion of qualitatively positive x-rays in NE, NW, SE, and SW regions was 10.8%, 10.5%, 12.4% and 3.8% respectively. X^2 test applied to this distribution of positive x-rays in various directions, was insignificant at 5% level ($X^2 = 5.16$, d.f. = 3). However, when various groups were compared, only the difference between the NE and SW region was significant ($d = 2.1$, $P < 0.05$).

C. Distance from the Industry: The results of the population study, according to the distance from the industry, are shown in Table 6.

ppm (S.D. ± 1.78 ppm), significantly higher than that of 23 subjects in a control sample ($X = 1.33$ ppm, S.D. ± 0.791) ($Z = 3.245$, $P < 0.01$). The fluoride level was more than 4.5 ppm in 36 (9.2%).

Of all x-rays taken in the study area, 39 (9.51%) showed qualitative radiological changes suggestive of new bone formation.

B. Region-Wise Distribution of Clinical Picture: The clinical symptoms, dental and x-ray changes, as well as fluoride excretion in spot urine samples in relation to wind direction are presented in Table 5.

Table 4

Prevalence of Fluorotic Dental Changes
Age Groups and Sex

Fluorotic Dental Changes	Age (years)			Total	Male	Female
	0-7	7.1-14	14+			
Present	357 (18.8)	707 (41.0)	601 (17.5)	1665	737 (23.7)	928 (23.4)
Absent	1540	1016	2838	5394	2368	3026
Total examined	1897	1723	3439	7059	3105	3954

Figures in parenthesis indicate prevalence rate (%).

Table 5
Results of Population Study

Parameters	Wind Directions			
	NE	NW	SE	SW
Spot urine samples Mean	2.18	2.12	1.54	1.91
S.D.	2.11	1.94	1.27	1.15
Number	172	58	122	43
Samples with 4.5 ppm and more	11.04	15.51	4.91	4.66
Proportion of examined persons having				
a) Health complaints	20.45	15.75	18.11	12.90
b) Spinal complaints	13.49	10.27	9.48	7.69
c) Joint pain	10.61	8.02	10.14	6.91
Persons with fluorotic dental changes	24.69	23.48	20.03	25.13
X-rays showing fluorotic changes	10.8	10.5	12.4	3.8

The proportion of examined persons with complaints was significantly higher in category III area (24.52%) than in category II area (15.75%), ($d = 5.11$, $P < 0.001$) and in category IV area (14.29%) ($d = 6.22$, $P < 0.001$).

The prevalence of fluorotic dental changes was 23.9%, 23.84% and 22.94% in areas II, III and IV respectively. However, the prevalence of dental changes and distance from the industry were not related ($X^2 = 1.06$, d.f. = 2, $P > 0.05$).

Mean urinary excretion in spot samples was significantly higher in the distant area IV namely 2.14 ppm than in the nearby area II, namely 1.69 ppm ($Z = 2.07$, $P < 0.05$). Similarly the proportion of urine samples with > 4.5 ppm fluoride was significant in the distant area IV, namely 11.42%. In area III it was 10.25%, compared to the nearby area II, namely 4.05% (d values for II and III = 1.97, $P < 0.05$ and II and IV = 2.2, $P < 0.05$).

Table 6
Population Study According to Distance from Industry

		Distance from Industry		
		II (500-1500 m)	III (1500-2000 m)	IV (2500-3500 m)
1) Spot urine samples	Mean	1.69	1.93	2.14
	S.D.	1.19	1.72	2.15
	Samples	94	156	140
	Proportion of samples with 4.5 ppm and more	4.05	10.25	11.42
2) Proportion of examined person with				
a) Health complaints		15.75	24.52	14.29
b) Spinal complaints		9.76	13.03	8.86
c) Joint pain		8.18	12.23	7.07
3) Proportion of examined persons with fluorotic dental changes		23.9	23.84	22.94
4) Proportion of x rays showing fluorotic changes		5.4	12.8	10.2

The proportion of qualitatively positive x-rays in areas II, III and IV was 5.4%, 12.8% and 10.2% respectively. Comparison of different areas revealed that the proportion of positive x-rays was higher in the distant areas III and IV combined, namely 11.7%, than in the nearby area II (5.4%) ($d = 2.27$, $P < 0.05$).

Discussion

Preskeletal symptomatology in neighborhood fluorosis, which largely depends on the amount of fluoride emitted by the industry and fluoride intake, was described in detail by Waldbott et al. (2) who found that joint and spinal cramps were main complaints. The same observations were made in the present study. Arthritis of spine and small joints of hands and fingers develops early in the course of the disease with or without demonstrable radiological changes (3,4). Chizzola maculae, a skin lesion characteristic of industrial fluoride exposure (2,5), was not seen in the present study. Occurrence of this skin lesion, however, depends on distance from the factory, fluoride concentration in the air, as well as skin complexion and texture of the individual (6). The skin lesions tend to fade when exposure to fluoride fumes is discontinued (7).

Children, apart from dental changes are not likely to show bone changes demonstrable by x-ray (8) from excess industrial fluoride exposure. They may, however, suffer preskeletal symptoms (9) which are not recognized as fluoride connected. Teeth exposed to fluoride during their developmental period may show fluorotic dental changes. Hunter (10), therefore, concluded that dental fluorosis should be regarded as a sign of neighborhood fluorosis rather than industrial fluorosis. Fluorotic dental changes in adults (above age 14) in the present study are, therefore, difficult to explain in the light of present knowledge. The level of fluoride exposure, at which dental changes occur, is not precisely known. It differs from one individual to another. Roholm estimated it to be 0.1 mg/kg of body weight per day (11).

The task of assessing damage to human health by fluoride is extremely difficult (12). Available evidence (health complaints, fluorotic dental changes, urinary fluoride excretion and radiological changes), in absence of a high concentration of fluoride in drinking water, clearly indicates the existence of neighborhood fluorosis and involvement of human beings; due to excessive intake of fluoride in animals through grossly contaminated forage, the problem of animal fluorosis became evident earlier than that of human fluorosis. When fluoride in drinking water is low, food and air appear to be the source of fluoride from the environment to man. High urinary fluoride in the NE region and highly positive x-rays in the area distant from industry (11.7% in category III + IV compared to 5.4% in II), also suggests that man is affected by fluoride-containing gas (see "Discussion" in Part I, Paragraph 3).

The present study, carried out 10 years after the factory started to function in 1966, provides evidence of skeletal fluorosis in nearly 10% of x-rayed adults. Most of the studies on neighborhood fluorosis, reported to date, were carried out either near an aluminum industry or an iron foundry, where fluoride compounds are used as flux (2,11,13,14) whereas

the present study was carried out in the environs of a fluoride-processing industry manufacturing Freon, a refrigeration gas. Although preliminary, the first of its kind in India, this study is expected to serve as a baseline for future studies in this area.

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