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Biological Monitoring of Urinary Fluoride Among Phosphate Fertiliser Production Industrial Workers

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Abstract

Objectives: Fluoride pollution at the workplace environment arises mostly due to anthropogenic activities. The workers working in phosphate fertilizer industry might have chronic exposure to excessive fluoride which can cause adverse health effects. Therefore, the present study was designed to assess urinary fluoride levels in occupationally exposed workers. **Methods:** In this study, pre and post-shift urinary samples were collected from phosphate fertilizer industry male workers (n=53). Fluoride levels in urine samples were analysed using an Ion Selective Electrode (ISE). **Findings:** The mean concentration of pre-shift and post-shift urinary fluoride levels were 2.14±1.35 and 2.42±2.02 mg/g of urinary creatinine respectively. Workers' pre-shift mean urine fluoride levels were categorised according to their working departments. Workers from the manufacture plat of Single Super Phosphate (SSP), Granular Single Super Phosphate (GSSP), maintenance, and administration had fluoride levels of 2.87±1.88, 2.43±1.01, 2.16±1.30, and 0.92±0.601 mg/g of urine creatinine, respectively. Similarly, the post-shift urinary fluoride levels were 3.68±3.00, 2.64±1.85, 2.24±1.78 and 1.14±0.53 mg/g of urinary creatinine in these departments respectively. One-way analysis of variance shown significant difference in urine fluoride concentrations between pre-shift (ANOVA, df=3, F=4.717; p=0.006) and post-shift samples (ANOVA, df=3, F=2.895; p=0.044). About 22.64 % of subjects in the pre-shift and 3.77% of subjects in the post-shift had exceeded the urinary fluoride limits prescribed by various statutory agencies. **Novelty:** Based on pre-shift and post-shift work exposure assessments, this study adds new knowledge to scientific research on the fluoride exposure among phosphate fertiliser sector workers. While there is sporadic information on fluoride levels among various other occupational groups, very few reports reported the fluoride levels in fertilizer industry workers. Outcomes of this study will help to identify the source of fluoride and extent of fluoride exposure so as to suggest the mitigation measure to control fluoride exposure at occupational settings.

Keywords: Biological monitoring; Fluoride exposure; Urinary fluoride; Occupational fluoride exposure; Fertilizer industry workers

1 Introduction

Fluoride is widely distributed in the Earth's crust, mostly in the form of minerals fluorite (fluorspar), fluorapatite (phosphate rock), and cryolite, which contaminate ground water source[1,2]. However elemental fluorine is almost never found in nature. The primary causes of fluoride pollution in the environment include geological processes like leaching and weathering of rocks and human actions including burning coal, smelting metals, making phosphate fertilisers, using fluoride-containing insecticides, and phosphate fertilisers that contaminate soil with fluoride[3–5].

In India, due to development of industrial infrastructure and urbanization, use of fertile land for farming is declining. Due to the country's limited resources for arable land and the load of growing population, the primary goal of the government is to increase farm productivity by using the chemical fertilizer to meet the demand for food[2,6,7]. Throughout the world, phosphate fertilizer production depends on mining of rock phosphate. Due to the raw material shortage, our country fully depends on the high-grade imported rock phosphate[2]. Major contribution of fluoride in the Vicinity of phosphate fertilizer industry is dust falls from rock phosphate and phosphogypsum[3]. The emitted fluoride from the Phosphate fertilizer industry reaches the soil by deposition, air, rain, and fluoride contaminated plant residues[5].

Fluoride exposure studies conducted in humans especially among children living in fluoridated and non-fluoridated areas have reported the total daily fluoride intake, urinary fluoride and other biomarkers were higher in fluoridated area compared with non-fluoridated areas[8]. People staying in high altitude with low water fluoride areas showed low urine fluoride excretion and high fluoride concentration due to retention of dietary fluoride in the body[9]. There are some studies reported that the fluoride exposure leads to the nephrotoxicity in humans[10–13]. Most of the studies are community-based studies carried out for fluoride exposure but there is lack of studies among the workers, who get exposed while doing their job.

Emission of dust and gases from fertilizer industry is potentially harmful to workers and local environment. During the rock phosphate digestion process in the fertilizer industry, there might be emission of fluoride as dust and fumes. Exposure to fluoride might occur through inhalation of gaseous fluoride or particulate fluoride emitted during fertilizer manufacturing activities in the industry. Very few studies were carried out to assess urinary fluoride exposure in phosphate fertilizer industry workers. One study from India[14] reported post-shift urinary fluoride concentration among fertilizer industry workers, however, the source of fluoride in the human body might be due to various exposure pathways, and the work-related fluoride exposure was not elucidated. Since, there are no previous studies assessing the fluoride levels in both pre and post-shift work, the present study was aimed to assess pre and post-work shift urinary fluoride levels among workers in phosphate fertilizer industry.

2 Methodology

2.1 Study design and sample collection

This cross-sectional study recruited a total of 53 male workers working in a phosphate fertilizer production industry. The written consent was obtained from each participating employee. The workers' urine samples were collected prior to the start (pre-shift) and at the end of the shift (post-shift) in a 50ml sample container (Himedia) containing 0.2g of EDTA (Merck) and were stored in a cold storage box. Samples were transported to the laboratory without delay for further analysis.

2.2 Urinary fluoride analysis

Urinary fluoride analysis was carried out by following a NIOSH-8308 method[15]. The urine samples were analyzed for fluoride concentration using Ion Selective Electrode by ORION 4 STAR pH/ISE bench top meter (Thermo scientific). The fluoride Ion Selective Electrode was calibrated with five different working standard (Orion 940907) concentration (0.1, 1, 5, 10 and 100ppm) before analysis of the samples. The ratio of 1:1 for the standards/samples and TISAB-II solution (Orion 940907) were maintained. The TISAB-II solution provides constant ionic strength to the samples and standards. During analysis, same temperature was maintained for standard and samples. The stored urine samples were thawed to room temperature and 10ml of well mixed urine and 10 ml of total ionic strength adjustment buffer (TISAB-II) solution were taken into a 50ml plastic beaker. A stirring bar was added in the beaker containing the solution and continuously stirred on a magnetic stirrer at room temperature for 1-2 min, then immersed the electrode in the solution. After stabilization, fluoride concentration readings were measured in mg/L. To avoid the cross contamination, electrode and stirring bar was washed with distilled water and wiped with dry tissue after each sample. For quality control, blank and standard was tested in between every five samples. Spiked urine sample shows100% $\pm$ 2% recovery.

2.3 Urinary creatinine analysis

Urinary creatinine was determined by using LIQUIXX Creatinine (CRE) Kit in the semi auto analyser (Erba-CHEM-7). Finally the fluoride concentration in urine was expressed as mg of fluoride per gram of urinary creatinine (mg/g of crtn).

2.4 Data analysis

Statistical analysis was done using the Statistical Package for Social Sciences (SPSS) software, version 26.

3 Results and Discussion

A total number of 53 workers participated in the study. Workers were categorized according to their nature of job into four groups namely SSP plant-production, GSSP plant production, maintenance and administration.

The urinary fluoride levels detected in pre-shift and post-shift urine samples collected among workers were 2.14 mg/g of urinary creatinine and 2.42 mg/g of urinary creatinine respectively (Figure 1). Although there is no statistical significance, higher concentration of urinary fluoride was measured in post-shift samples. It indicates that the workers were exposed to fluoride at shop floor during their shift.

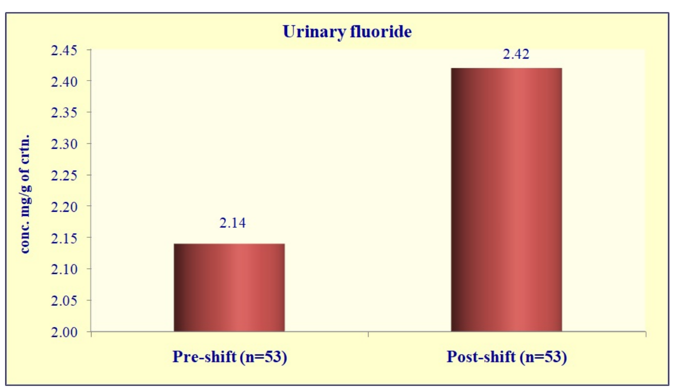

Fig 1. Mean urinary fluoride concentration (mg/g of urinary creatinine) among phosphate fertilizer workers

In the present study, the pre-shift urinary fluoride levels (2.14$\pm$1.35 mg/g of crtn) detected were marginally higher than the pre-shift urinary fluoride level (1.31$\pm$0.77 mg/g of crtn) reported in aluminium smelter workers in USA[16] (Table 1). However, the post-shift urinary fluoride levels in the present study are (2.42$\pm$2.02 mg/g of crtn) comparable with the post-shift urinary floured levels (3.02±1.87 mg/g of crtn) reported in same aluminium industry workers in USA. An another study conducted in aluminium smelter workers in Slovakia reported pre and post-shift urinary fluoride levels of 0.455±0.353 mg/g of crtn and 0.957±0.686 mg/g of crtn respectively[17]. However, in the present study, fluoride levels were higher than the levels reported in aluminium smelter workers of Slovakia.

Table 1. Comparison of urinary fluoride levelsreported among workers in industry

Reference	workers	Country	Type of urine samples	Pre-shift-Fluoride levels (mg/g creatinine)	Post-shift-Fluoride levels (mg/l)
Present study	Phosphate fertilizer industry	India	Pre & post shift	2.14±1.35	2.42±2.02*
Arshad & Shanavas[14] 2013	Fertilizer industry workers	India	Post-shift	-	3.85±1.66
Seixan et al[16] 2010	Aluminium Smelter workers	USA	Pre & post shift	1.31±0.77	3.02±1.87*
Susheela et al[18].2013	Aluminium Smelter workers	India	Spot urine	-	5.09
Khanoranga & Khalid[19] 2019	Brick kiln workers	Pakistan	Spot urine	-	0.17-0.30

*Indicates that urinary fluoride levels in mg/g creatinine

In India, a study by Arshad and Shanavas[14] in fertilizer industry reported post-shift urinary fluoride levels of 3.85±1.66 mg/L and Saha et. al,[20] reported post-shift urinary fluoride levels in metal smelting workers (Other areas- 0.090±0.068 mg/dl and Pot line- 0.190±0.139 mg/dl) however, direct comparison with the current study was not possible due to the differences in unit reported, where current study values are corrected based on urinary creatinine levels.

The urinary fluoride concentration (mean±SD) in pre-shift based on various departments were 2.87±1.88, 2.43±1.01, 2.16±1.30 and 0.92±0.60 mg/g of crtn in the SSP plant-production, GSSP plant-production, maintenance, and administration respectively (Figure 2). Similarly the post-shift urinary fluoride levels were 3.68±3.00, 2.64±1.85, 2.24±1.78 and 1.14±0.53 mg/g of crtn respectively. The urinary fluoride concentration among workers employed in SSP, GSSP and maintenance were compared with the administration as they were not directly exposed to fluoride at shop floor. It was observed that higher urinary fluoride levels were found among workers in the SSP plant-production followed by GSSP plant-production, maintenance and administration. The reason could be attributable to the digestion of rock phosphate taking place in the SSP plant, and hence the workers in this department are being exposed to high fluoride. The higher levels of urinary fluoride in worker of SSP plant indicate that the fluoride exposure levels are directly associated with workplace source.

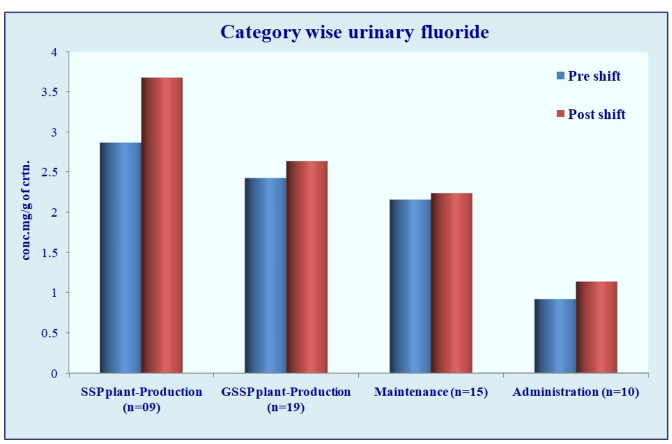

Fig 2. Urinary fluoride levels (mean) among workers in various departments

The significant difference was observed in urinary fluoride concentration among various department workers, tested for both pre-shift (ANOVA, df=3, F=4.717; p=0.006) and post-shift (ANOVA, df=3, F=2.895; p=0.044). Further, multiple comparison by

Bonferroni post hoc test for pre-shift concentration tested indicate that the workers in SSP (p=0.007) and GSSP (p=0.017) plant have higher exposure than the administration. Whereas post-shift levels tested in SSP plant was higher than the administration (p=0.036), however, there was no difference observed in fluoride levels measured among other departments tested. This result clearly indicates the differences in exposure levels among different department and variation in fluoride sources depending on raw materials used and types of process carried out in each department. Urinary fluoride concentration was less among the administration department workers, which directly demonstrates that the exposure was less in these workers due to their nature of job and that they were working far away from process areas and sitting in the closed environment.

In our investigation there was no significant differences observed in urinary fluoride levels based on age categories (ANOVA, p>0.05) (Table 2). In children and adults, renal clearance rates did not differ with age. However, in older adults (over 65 years of age), there is a significant reduction in renal clearance of fluoride as a result of age-related glomerular filtration rate reductions, with most fluoride retained in bones and teeth of the human body[19].

Table 2. Urinary fluoride concentration (mg/g of urinary creatinine) among workers based on their age group

Age groups	Shifts	Statistics		
		Mean±SD	**Range**	**Median**
20-35 (n=16)	Pre shift	2.28±1.53	0.28–6.38	1.69
	Post shift	2.82±2.59	0.63–10.26	1.79
36-45 (n=24)	Pre shift	2.11±1.25	0.18–4.79	2.01
	Post shift	2.15±1.41	0.59–5.88	1.61
>45 (n=13)	Pre shift	2.03±1.39	0.74–5.56	1.25
	Post shift	2.41±2.27	0.71–9.27	1.75

The participated workers were further classified into temporary and permanent based on their nature of appointment in the industry. Table 3 shows, the urinary fluoride levels of temporary workers were significantly higher than the permanent workers both in pre-shift (t=3.778, p=0.0002) and post-shift (t=3.447, p=0.0005). In general, the temporary workers are made to work in all the areas and their duration of working hours may be longer compared to the permanent workers. The permanent employees, on the other hand, will work at the designated hours in the designated locations. It was also noted that the permanent workers were using the respiratory protection equipments regularly compared to the temporary workers. Hence educating the temporary workers on importance of using safety appliances is highly recommended. Additionally, the management should provide all adequate safety appliances to such workers considering the affordability of an individual worker to buy the safety appliance.

Table 3. Urinary fluoride concentration (mean±SD, mg/g of urinary creatinine) among temporary VS permanent workers

Shifts	Temporary workers (n=29)	Permanent workers (n=24)	t-value	p-value
Pre shift	2.71 ± 1.31	1.46 ± 1.07	3.778	0.0002*
Post shift	3.21 ± 2.27	1.46 ± 1.11	3.447	0.0005*

For human growth and development, fluoride is not treated as an essential element, but it is treated to be beneficial in the prevention of dental caries[21]. Several studies state that an excessive exposure to fluoride will cause toxic effects, like dental and skeletal fluorosis as well as non-skeletal fluorosis[22]. Earlier studies have reported that due to anthropogenic activity, fluoride levels is high in the industrial workplace environment and it causes health effects to the people living near the industry and fluoride endemic areas[19]. In India this type of studies are limited among the phosphate fertilizer industry workers comparing pre-shift and post-shift urinary fluoride as biomarker of workplace fluoride exposure.

The results of the present study were compared with the exposure limits prescribed by the various agencies[23]. In our investigation the pre-shift urinary fluoride was exceeded the permissible limits in 12 out of 53 (22.6%) subjects. Two subjects out of 53 (3.77%) had exceeded the post-shift urinary fluoride, prescribed limits of ACGIH; BEI, DFG-BAT and NIOSH (Table 4). Although various confounding factors[24] such as lifestyle characteristics, dietary intake might be the contributing factor for urinary fluoride in the pre-shift urine samples and occupational exposure is the predominant role for urinary fluoride in the post-shift urine samples.

The absorption of the fluoride in the body relies on the chemical nature of the fluoride consumed. About 90% of body fluoride is absorbed into the bloodstream and remaining emitted in the faeces. Absorbed fluoride is taken up by calcifying tissues and it forms fluorapatite. About 45% of the blood fluoride is filtered in the kidneys and eliminated in the urine. Very

Table 4. Comparison of urinary fluoride levels with biological exposure indices (BEI) values prescribed by various agencies [23]

Different agencies	Shifts	Urinary Fluoride limits mg/g of Crtn.	% of subjects exceeded the prescribed limits (number)
ACGIH (BEI)	Pre shift (n=53)	3 mg/g of Crtn.	22.64 (n=12)
	Post shift (n=53)	10 mg/g of Crtn.	1.88 (n=1)
NIOSH & DFG-BAT	Pre shift (n=53)	4 mg/g of Crtn.	9.43 (n=5)
	Post shift (n=53)	7 mg/g of Crtn.	3.77 (n=2)

less amount of fluoride is discharged in other body fluids like saliva, breast milk and sweat. Additionally, some accumulated fluoride in the body's soft tissues has an impact on enzyme activity and absorbed by the pineal gland, which may calcify [21,25]. Ingested fluoride is typically found in the stomach of both humans and animals as hydrogen fluoride (HF). The HF is absorbed from the gastrointestinal tract into the blood and circulated throughout the body. The amount of urinary fluoride reflects the level of exposure at various sources; however, the high amount of post-shift urinary fluoride indicates the clear indication of occupational exposure to fluoride at workplaces as reported by earlier studies [21,26]. The typical short-term plasma fluoride half-life ranges from 3 to 10 hours. The primary method through which fluoride is eliminated from the body is through urine excretion. In kidney, fluoride ion in the blood is filtered before being partially reabsorbed. Numerous variables, including glomerular filtration rate, urine flow, and pH of urine, may have an impact on the excretion of urinary fluoride [21,26]. Therefore, the usage of personal protective equipment (PPE) at the work environment is highly important to reduce the fluoride exposure at sources.

4 Conclusion

The present study documented fluoride levels in pre-shift and post-shift urine specimens among fertilizer industry workers. Urinary fluoride levels in the SSP production plant workers (pre-shift 2.87±1.88 and post-shift 3.68±3.00 mg/g of crtn) were higher than GSSP production plant (pre-shift 2.43±1.01 and post-shift 2.64±1.85 mg /g of crtn), maintenance (pre-shift 2.16 ±1.30 and post-shift 2.24±1.78 mg/g of crtn) and administration (pre-shift 0.92±0.60 and post-shift 1.14±0.53 mg/g of crtn). The major rock phosphate (raw material) digestion process was taking place in the SSP plant production and final product on granulation and packaging was at GSSP plant. This might be the major reason for detection of higher levels of urinary fluoride in the SSP plant compared to the GSSP plant. Prolonged exposure time was less in maintenance because they could not be exposed continuously at a particular place; it might be the reason for lower urinary fluoride levels. Post-shift urinary levels clearly indicate that individuals might be exposed more to fluoride at working place. Limitation of this study is concentrated towards studying the occupational exposure, however, the fluoride exposure route in human being is depends on dietary, environmental exposure along with occupational exposure. Therefore this current study recommends to focus on other aspect of exposure routes in future studies. Since there is no treatment for fluorosis, prevention is the only solution. In order to understand prevailing situation at work environment, monitoring the health status of workers and fluoride levels in body fluids is the best practice. Present study outcomes will help the employer to design a policy and intervention that aims to reduce the risk of potentially adverse effects of chronic exposure to excessive fluoride in the industry. The periodical fluoride evaluation should be conducted among the industrial workers to avoid possible exposure to the fluoride in the workplace environment. An awareness program should be conducted among the workers regarding the work place hazards, their health effects and safety procedures like wearing gloves, shoes, safety goggles, proper clothing, helmet, mask and earplugs to minimize the exposure levels among fertilizer industry workers.

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