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Serum Calcium and Phosphorus Levels in Nuclear Fuel Workers

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INTRODUCTION

Uranium is the fuel for the atomic power reactors and the manufacture of pure grade uranium fuel from the crude ore involves several steps. Workers engaged in these operations are likely to get exposed to different forms of uranium.

Whenever any noxious agent enters into the body it is bound to interact with the body fluids, thereby causing several biochemical changes. The major internal organs which could be affected by such agents are gastro-intestinal tract, lungs, liver, stomach, kidneys etc. Inhaled and ingested uranium enters blood stream through dissolution in the lung fluid and absorption from gastro-intestinal tract. Uranium at phyisiological pH exists in hexavalent state as uranyl ion, UO_2^{++} and it is capable of forming complexes with substances of biological interest such as HCO_2^-, PO_4^{3+}, OH^-, citrate ion, proteins and enzymes.

There are studies that evaluated the genotoxic (Martin et al., 1991; Prabhavathi et al., 1995) and health effects (Anthony and Frome, 1981) of workers employed in mining and processing uranium. Epidemiological studies have revealed increased risk for lung, extrapulmonary and respiratory cancers in uranium miners and processing plant workers (Roger and Morgan, 1993; Axelson and Forasstiere, 1993). However, studies on biochemical effects of uranium exposure in the workers are meagre.

Studies on animal models have revealed uranium as a nephrotoxin (Passow et al., 1961; Morrow et al., 1982; Morrow, 1984). In the case of humans, biochemical alterations were reported in the urine of workers with exposure to uranium. While Clarkson and Kench (1956) reported significantly higher levels of aminoacids, in the urine of 10 workers exposed to gaseous compound of uranium, Thun et al. (1985) reported significantly higher levels of b^2-microglobulin and various aminoacids in the urine of workers occupationally exposed to uranium.

So far, the biochemical changes observed due to uranium poisoning were studied mainly in animals and the human data available showed biochemical alterations in urine of the exposed individuals. Hence, an attempt has been made to analyse the calcium and phosphorus levels in the serum of workers employed in a nuclear fuel facility in order to evaluate the possible toxic effects of exposure to uranium on their metabolism in the body.

MATERIALS AND METHODS

Male workers employed at a nuclear fuel facility for a period of 1-25 years formed the subjects of the present study. Their age ranged from 23 to 52 years. The workers were thoroughly interviewed and information regarding their age, personal habits (smoking, alcohol consumption, tobacco and pan chewing etc.), type of job, health and reproductive performance was recorded.

Estimation of Serum Calcium and Phosphorus*:* Venous blood was collected from workers for estimation of serum calcium (n = 79) and serum phosphorus (n = 86) levels. For comparison blood samples were also collected from 35 individuals who never had any exposure to uranyl compounds or any known physical or chemical agent. All the samples were analysed using standard kits (OC PC method for serum calcium and modified Metol method for serum phosphorus) supplied by Monozyme India Ltd., Hyderabad, India. Men in both the exposed and control groups were non-smokers and non-alcoholics. Statistical analysis of the data was done using students t-test.

RESULTS AND DISCUSSION

Results on serum calcium and phosphorus levels in the nuclear fuel workers are presented in tables 1 and 2. The mean serum calcium level observed in the exposed group increased to 12.40 mg/dL from 9.53 mg/dL in the control group. The

Table 1: Analysis of serum calcium levels in nuclear fuel workers

Group and duration of exposure (years)	*Number of samples analysed*	*Mean ± S.D (mg/dL)*
Control group	35	9.53 ±1.65
Exposed group		
1 - 10 years	27	10.95 ±1.54
11 - 20 years	35	12.55 ±2.95*
> 20 years	18	13.58 ±1.54*
Total (1-25 years)	79	12.40 ±1.78*

* $p < 0.001$

Table 2: Analysis of serum phosphorus levels in nuclear fuel workers

Group and duration of exposure (years)	*Number of samples analysed*	*Mean ± S.D (mg/dL)*
Control group	35	3.75 ±0.69
Exposed group		
1 - 10 years	39	5.15 ±0.70
11 - 20 years	37	8.32 ±1.25*
> 20 years	19	8.30 ±1.20*
Total (1-25 years)	86	6.77 ±1.05*

*$p < 0.001$

periodwise analysis showed that the groups with 11-20 and >20 years of exposure to uranyl compounds showed a significant increase in serum calcium levels when compared to the control group (Table 1). The mean serum phosphorus level observed in the exposed group was 6.77 mg/dL whereas in the control group it was 3.75 mg/dL. The difference between these two means was significant ($p<0.001$, Table 2). Periodwise analysis revealed a gradual increase in the levels of serum phosphorus and calcium in the exposed group and this increase was significantly higher when compared to the respective control value.

Our present study showed significant raise in calcium and phosphorus levels in the serum of nuclear fuel workers. This might be due to cell damage in renal tubules and impaired absorption from gastrointestinal tract and these impairments may be occuring from uranium poisoning. In support of our findings, Stefonovic et al. (1987) also revealed increase in calcium and phosphorus levels in the serum of dogs after treated with uranyl nitrate.

Our earlier reports on nuclear fuel workers, revealed mean uranium burdens of 95.3 mSv in nonsmoking workers and 90.8 mSv in smoking workers. In addition to this we reported significant elevation in the incidence of SCEs (Prabhavathi et al., 1995) and chromosomal aberrations (Prabhavathi et al., 2000) in smoking and non-smoking nuclear fuel workers.

Animal studies also have provided evidence for nephrotoxicity of uranium. Morrow et al. (1982) reported renal damage resulting in proteinuria in dogs after moderate exposure to uranium. Studies have revealed renal dysfunction resulting in glycosuria in animal models after exposure to uranium (Passow, 1961; Morrow, 1984). Renal leisons of tubules, glomeruli and interstitium were reported in Sprague-Dawley rats after 91-day exposure to uranium (Gilman et al., 1998). Another study (Das and Joshi, 1989) reported acute damage of kidneys in goats after treatment with 1% uranyl nitrate intravenously. This study indicated conditions like polyuria, oliguria, albuminuria, glycosuria etc.

The increased levels of calcium and phosphorus in the serum of nuclear fuel workers indicate renal damage. Humes (1986) and Weinberg (1988) reported that calcium loading might play particularly an important role in the pathogenesis of renal tubular cell injury because of normally high transcellular transport of calcium across renal tubular epithelium. However, further studies on humans are required to generate data on uranium and radiation toxicity.

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KEY WORDS Uranium. Nuclear Fuel. Occupational Exposure. Calcium. Phosphorus.

ABSTRACT Biochemical studies were carried out in the workers from various plants of a nuclear fuel manufacturing facility. Their age ranged from 23 to 52 years and their service in the nuclear fuel facility ranged from 1 to 25 years. Serum calcium levels were estimated in 97 workers and serum phosphorus levels were analysed in 86 workers using standard kits. For comparison, 35 individuals who had no exposure to uranyl compounds or any other known chemical or physical mutagen were also studied. Both worker and control groups were non-smokers and non-alcoholics. A significant rise in serum calcium and phosphorus levels was observed in the workers when compared to respective controls, indicating renal damage.

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