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Susceptibility To Infection Among Nickel Electroplaters

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Abstract

Background:Assessment of environmental, microbiological and immunological hazards among nickel electroplating worker shop was the goal of this study as electroplating processes result in the emission of soluble nickel compounds aerosoles causing health hazard .Materials and Methods:Study of 50 workers in a nickel electoplating work shop compared to 30 matched controlswas done. Personal interview, clinical examination , investigations of urinary & serum nickel, ventilatory function tests, IgA and IgE immunoglobulins, and microbial profile of oganisms causing chronic bronchitis and dermatitis and estimation of the environmental air of the work shop were performed . Results: showed low levels of IgA and high levels of IgE among the exposed workers. Reduction of spirometric measurements but not to the level of significance. Statistically significantly positive correlation was found between IgE and serum & urinary nickel of exposed workers. In addition, The frequency of skin affection, in form of itching (68%), skin erythema ,eruptions (64%) and dermatitis (58%), among the exposed workers was statistical significantly higher compared to control group. Ezemattic individuals were colonized with *Staph.*species ; *S.aureus & S.epidermidis,* exposed workers showed more percentage than control;(32%&16%)and(3.3%&6.7%)forthecontrolrespectively.Whereas,*Streptococcus pyogenes* colonized (10%) of exposed workers only. *Streptococcus pneumonia* and other Gram-positive cocci, e.g *Staphylococcus aureus* constituted most of the microbial parameters colonized the individuals complained from chronic bronchitis. Conclusion and recommendation:We recommended periodic medical chest examinationand, microbiogical profile,measuring nickel level in body fluid and recommended the use of chelating agents for those with high levels. [Journal of American Science 2009:5(3) 74-82] (ISSN: 1545-1003)

Key words:Occupational nickel exposure,immunology,chronic bronchitis,dermatitis

1. Introduction

Occupational exposure to nickel occurs predominantly in mining, refining, alloy production, electroplating, and welding. Nickel electroplating is extremely well-known and widely applied.

The most common metals used in plating are chromium, nickel, cadmium, zinc, copper, silver, gold and, more rarely, rhodium. In nickel plating the solutions used include: nickel sulphate with boric acid and nickel chloride. Electroplating processes generally result in emissions of aerosols of soluble nickel sulphate or chloride, depending on the nickel form used in the electrolyte (IARC,1990).

Kidneys, lungs and immune system were found to be the target organs for chronic nickel toxicity (Coogan et al.,1989). Chronic inhalation exposure to nickel dusts and aerosols contribute to respiratory disorders such as asthma, bronchitis, rhinitis, sinusitis, and pneumoconiosis (Das et al.,2008).

The histological changes noted in the lungs included alveolar wall damage with fibrotic changes and oedema in the alveolar space (Baker et al.,1985).

The most common harmful health effect of nickel in humans is an allergic skin reaction in those who are sensitive to nickel. Nickel is the most observed cause of immediate and delayed hypersensitivity noticed in occupationally exposed as well in the general population.The metal is not only an allergen but also a potential immunomodulatory and immunotoxic agent in humans (Das and Buchner , 2007).The nickel-containing material reacts with sweat to form nickel ions that penetrate the skin.The soluble compounds dissolve in the lung's mucous membranes triggering a non-cancerous inflammation (INCO, 2002) .

The investigations of the pathogenic effects of nickel greatly benefit from the understanding of the chemical basis of Ni(II) interactions with intracellular targets/ligands and oxidants. Many pathogenic effects of nickel are due to the interference with the metabolism of essential metals such as Fe(II), Mn(II), Ca(II), Zn(II),orMg(II)(Kazimierz et al.,2003).Excessive nickel in tissues is pro-

oxidant (damaging chromosomes and other cell components) and alters hormone and enzyme activities, movement of ions through membranes, and immune function. These effects can change glucose tolerance, blood pressure, response to stress, growth rate, bone development and resistance to infection.

Aim of the work: We aimed at assessment of environmental, microbiological and immunological hazards among nickel electroplating workers shop is our main goal.

2. Methods

Our study design was a cross sectional case-control one. The exposed subjects were 50 male workers that conistitute the whole working force in this nickel-electroplating work-shop. Their mean age was 41.6 ± 7.6 years, and mean duration of employment was17±5.5yrs.A30 control subjects were enrolled in our study from the administrative department of the work-shop, matched for age (mean 39± 7.1 yrs), sex, socio-economic status, smoking habits. The rank order of nickel exposure was estimated by job description and years of employment.

Workers were exposed to nickel aerosols while dealing directly with electroplating tanks (bath workers, hangers and solution makers). Workers were directly exposed the whole shift to nickel aerosols as the baths were covered only after work. No general mechanical ventilation was installed and no local exhausts existed above the baths in these workshops.

During the health survey an individual interview was conducted with all the electro-platers and the referent group. Subjects' evaluation included full clinical examination and the following investigations:

- Static ventilatory function testing.
- Immunological assessment in the form of measuring, IgA, IgE.
- Exposure assessment by measuring urinary and serum nickel, where sample collection time was standardized (mid day , mid working week).
- Sputum analysis for microbobial parameters causing chronic bronchitis

3. Microbiological Study

1- For subjects sufferring from chronic bronchitis, sputum samples were collected in a sterile vial and sent within 2 h to a laboratory for processing
2- For those with chronic eczema, saturated skin swabs from eczematous lesions (the infected fissures) and sent within 2 h to a laboratory for processing

Using the microbiological loop, 0.01 ml sputa and the swabs from eczematous lesions were processed microbiologically for study following accepted laboratory methods (Balows ,1991; Al-Saimary et al.,2006) .

Specimens were seeded in the following culture media: Brain Heart Infusion Broth (BHIB), mannitol salt agar (MSA),blood agar, MacConkey agar(for 24 hours at 37 °C) , chocolate agar(the atmosphere contained 5 to 7% Co_2.), and Sabouraud's agar plus chloramphenicol (at 35 ± 2°C in aerobic conditions). In the case of the chocolate agar, a first reading was taken after 24 h, and a second final one was taken after 48 h of culture.Three types of Api-technique (bioMerieux,France) were used as a rapid identification system for identification of the various bacterial isolates based on enclosed instruction :

1-Api staph. identification system for *staphylococci*

2-Api stept. identification system for *streptococci*

3-Api 20 E identification system for *Enterobacteriaceae* and other Gram –negative rods

Bacterial agents recovered from bronchial samples were classified into three groups:

1- Group (1): *Pseudomonas aeruginosa*, *Enterobacteriaceae* spp.(e.g *Proteus spp, Citrobacter freundii, Escherichia coli, Serratia marcescens*)
2- Group (2): *Streptococcus pneumonia* and other Gram-positive cocci, e.g *Staphylococcus aureus*,.
3- Group (3): Gram-negative cocci, e.g. *Moraxcella catarrhalis*.

4. Environmental assessment

The studied work shop of nickel-electroplating contains four tanks. Air sampling for nickel aerosols were measured in the breathing zones around each tank, at the center, at the enterance and at the end of the work shop. Each site was meaured three times and the mean level of nickel aerosols was calculated. Airborne nickel concentrations in this facility was followed for one workday at the same time as the

urinary and serum specimens were collected from the platers. All air samples were collected as whole shift samples.

5. Results

Table (1) Breathing zone air monitoring of soluble nickel salts at the work place

Site of air sampling	Breathing zone air concentration of nickel
At the 1st tank	1.8 mg m-3
At the 2nd tank	2.2 mg m-3
At the 3rd tank	1.9 mg m-3
At the 4th tank	2.5 mg m-3
At the enterance of the work-shop	1.4 mg m-3
At the center of the work-shop	1.38 mg m-3
At the end of the work-shop	1.32 mg m-3
Mean ± S.D.	1.86 ± 0.44 mg m-3

The highest nickel concentration in the electroplating work-shop was found near the 4th nickel tank 2.5 mgm-3. All the tanks were located at the same ward. The mean nickel air concentration was 1.86 ± 0.44 mgm-3 (table 1).

Table (2) Health survey manifestations among the studied workers

Adverse health effects	Referent group (n=30) No. %	Exposed group (n=50) No. %	Yates- corrected $\chi 2$ test	P- value
Chest manifestastions:				
- Asthma		22 44	7.54	<0.05
- Chronic bronchitis		32 64	6.52	<0.05
- Epistaxis		9 18	3.25	<0.05
- Perforated nasal septum		2 4	0.78	>0.05
Skin manifestations:				
- Itching		34 68	17.67	<0.05
- Erythema and eruptions		32 64	15.45	<0.05
- Contact dermatitis		24 58	12.18	<0.05

The frequency of skin affection, in the form of itching (68%), skin erythema and eruptions (64%) and dermatitis (58%), among the exposed workers was statistically significantly higher compared to control group. Our results demonstrated that the prevalence rate of asthma was 44% among nickel-electroplating workers. In addition statistically significantly higher prevalence of chronic bronchitis (64%) was found among our exposed workers compared to the control group (table2)

Table (3)Microbial parameters causing adverse health effects

Microbial parameters causing adverse health effects	Referent group (n=30) No. %	Exposed group (n=50) No. %
1-Chronic bronchities: **Group*1***		
Pseudomonas aeruginosa	-	6/50 (12%)

& Enterobacteriaceae		
Group 2		
Gram-positive cocci *Staphylococcus aureus, Streptococcus pneumoniae*	2/30 (6.3%)	25/50 (50%)
Group 3		
Gram-negativecocci *Moraxcella catarrhalis*	-	1/50 (2%)
Total	2/30 (6.3%)	32/50 (64%)
2-Skin dermatitis*:*		
A-Staphylococci species:		
Staph aureus	1/30 (3.3%)	16/50 (32%)
Staph epidermidis	2/30 (6.7%)	8/50 (16%)
B-Streptococcus pyogens	- -	5/50 (10%)
Total	3/30 (10%)	29/50 (58%)

Table (3) illusterated microorganisms colonized the individuals complainting from chronic bronchiti Group (2) composed from *Streptococcus pneumonia* and other Gram-positive cocci, e.g *Staphylococcus aureus* constituted most of the microbial parameters(50%) .Whereas, eczemattic individuals were colonized with staph.species (*S.aureus & S.epidermidis* (32% &16%) more than control (3.3% &6.7%) respectively.While, *streptococcus pyogens* colonized (10%) of exposed workers .

Table (4) Spirometric results of the studied population:

Spirometric tests	Referent group Mean S.D	Exposed group Mean S.D	Kruskal-Wallis test	P-value
VC % oredicted	101.8 3.2	90.3 8.7	4.8	>0.05
FVC% predicted	104.9 4.1	88.6 12.6	6.5	>0.05
FEV1% of FVC	99.3 4.8	93.9 6.4	1.8	>0.05
FEF50%	99.2 9.2	97.5 3.2	0.15	>0.05
FEF25%	98.4 4.1	96.4 6.5	0.24	>0.05
FEF 25-85%	98.1 3.6	97.8 3.6	0.03	>0.05

Otolaryngeal examination of our studied subjects revealed only two cases with perforated nasal septum and nine cases (18%), with history of repeated epistaxis(table (4).

Table (5)Immunological parameters among the studied population:

Immunological parameters	Referent group Mean S.D	Exposed group Mean S.D	Kruskal-Wallis test	P-value
Immuonological tests:				
- IgE (mg/dL)	1149.7 618.7	4864.5 2073.9	30.86	<0.01
- IgA (mg/dL)	1842.4 595.2	968.9 481.7	19.37	<0.01

Statistically significantly lower level of IgA among exposed workers compared to the control workers & significantly higher levels of IgE among the exposed workers than among the controls (table 5).

Table(6) Concentration of nickel in urine and serum in the studied population:

	Referent group Mean S.D	Exposed group Mean S.D	Kruskal-Wallis test	P-value
Urinary nickel (Ugm/L)	1.51 0.24	2.9 0.56	22.3	<0.01
Serum nickel (Ugm/L)	1.43 0.6	3.4 0.61	24.6	<0.01

Statistically significantly higher mean values of nickel in urine (Ni-U) and nickel in serum (Ni-S) were found in the exposed workers compared to the control group (table 6).

Table (7) Correlation coefficient between immunological parameters and serum and urinary nickel levels among nickel-electroplaters:

	Serum nickel (Ugm/L) r P value	Urinary nickel (Ugm/L) r P value
Immuonological tests:		
- IgE (mg/dL)	0.63 <0.05	0.65 <0.05
- IgA (mg/dL)	-0.66 <0.05	-0.60 <0.05

Table (7) demonstrated a statistically positive significant relation between the level of both Ni-S and Ni-U and the level of IgE.The level of IgA showed a statistically negative correlation with Ni-S and Ni-U.

Discussion:

Workers engaged in nickel production in hydro-metallurgical processes such as electroplating operations were believed to have quite high levels of nickel (>10 mg Ni m^{-3}). Recent estimates were much lower (1mg Nim^{-3}) (US Environmental Protection Agency,1993). In the present study, the breathing zone air monitoring was carried out in 7 different sites in the addressed electroplating work-shop. In 1990, the International Committee on Nickel Carcinogenesis in Man (Harry,1990) suggested that respiratory cancer risks are primarily related to exposure to soluble nickel concentrations above 1 mg $m^{-3}$and to exposure to less soluble forms at concentrations above 10 mg m^{-3}. Measurement exceeded the current occupational exposure standard set recently by the OSHA for nickel aerosoles 0.1 mg m^{-3}. Our results found the highest nickel concentrations in the air were found near the 4^{th} nickel tank 2.5 mg m^{-3}. All the tanks are located at the same ward. The mean nickel air concentration was 1.86 ± 0.44 mg m^{-3}.

Historically, nickel studies have focused on long-term respiratory (lung and sinonasal cavities) cancer effects, but other non-carcinogenic respiratory effects have occasionally been reported in workers as well.

United State Air Force (Harry,1990) reported that chronic inhalation exposure to nickel dusts and aerosols contribute to respiratory disorders such as asthma, bronchitis, rhinitis, sinusitis, and pneumoconiosis. Fernández-Nieto et al.,(2006) concluded that chromium and nickel salts can give rise to occupational asthma in exposed workers and the underlying mechanism may be IgE-mediated in some cases.

The exposed population of workers in our research demonstrated statistically significantly higher frequency of skin affection in the form of itching (68%), skin erythema and eruptions (64%) and dermatitis (58%), compared to the controls. This was consistent with the published findings of Coogan (Coogan et al.,1989; Wall and Calnan,1980), who concluded that the most common adverse effects of nickel exposure were skin allergies, specially dermatitis. Barceloux ,1999) concluded that nickel was a common sensitizing agent with a high prevalence of allergic contact dermatitis. Nickel dermatitis usually begins as papular erythema of the hands. The skin gradually becomes eczematous and in the chronic stage, lichenification frequently develops. Nickel sensitization also causes conjunctivitis, and oesinophilic pneumonitis (Loeffler's syndrome) (Sanderman et al.,1986). Rhinitis, nasal sinusitis and nasal mucosal injury were among the effects reported in workers chronically exposed to nickel compounds (Coogan et al.,1989).

Evidence for respiratory effects other than cancer rests mainly on a few reports of isolated incidents of asthma, pulmonary fibrosis, chronic bronchitis, and emphysema in nickel workers. Asthma has been reported in nickel platers exposed to nickel sulphate and in welders exposed to nickel oxides (Barceloux ,1999). The sparsity of reported cases of asthma and other non-malignant pulmonary effects probably accounts for the reason why such effects have not been the focus of epidemiological studies (IPCS,1991). In contrast to these studies our research results demonstrated that the prevalence rate of asthma was 44% among nickel-electroplating workers. This high prevalence may be explained by the very high level of nickel exposure that was encountered in our studied work shop (1.86 ± 0.44) and long duration of exposure (17 ± 5.5 yrs.).

Statistically significantly higher prevalence of chronic bronchitis (64%) was found among our exposed workers compared to the control group. (*Streptococcus pneumonia* and other Gram-positive cocci, e.g *Staphylococcus aureus*)constituted most of the microbial parameters colonized the individuals . Investigators also provided biologic plausibility for the role of (particulate matters (PM) associated metals, particularly Fe and Ni, in exacerbating *S. pneumoniae* infections in concentrated ambient PM -exposed hosts (Zelikoff et al.,2002**)**

The explaination was provided by the experimental study conducted by Dunnick ,et al.,(1989) who reported that the most sensitive parameter of nickel toxicity was histopathological changes in the lungs that were in the form of chronic active inflammation, fibrosis and alveolar macrophage hyperplasia. An in vitro model was studied by Adalis et al.,1978) to measure the effect of graded concentrations of nickel on ciliary activity. It was apparent that nickel can significantly decrease the ciliary beating frequency and interfere with the normal functioning of respiratory defense mechanisms, thereby,

increasing the risk of the host to respiratory infections. Other animal studies have also led to speculation that nickel may play a role in increasing susceptibility to lung infection through the direct effects on T-cell mediated responses and suppression of natural killer cell activity (Nicklin and Nielsen ,(1998).

Our results revealed colonization of eczemattic individuals with *Staph.*species (*S.aureus &S.epidermidis* (32% &16%) more than control (3.3% &6.7%) respectively.Whereas, *Streptococcus pyogenes* colonized (10%) of exposed workers only. In agreement with our results, Al-Saimary ,2006; Gong et al.,2006) confirmed that lesional skin of patients with eczema was mainly was more frequently colonized with *S. aureus* than was nonlesional skin. Many studies illustrated the factors whose relevance to the increased colonization of atopic dermatitis skin with bacteria -in general- and with *Staph. aureus* -in especially- such as produce of exotoxins((Ramirez,et al.,2002), ability of bacterial types to adherence with host cells of atopic skin(Abeck and Mempel, (1998). pH values were shifting toward alkalinity with adherence of *Staph. aureus* to human keratinocytes being highest at pH= 7-8(Nicklin and Nielsen ,(1998). Extracellular lipids of stratum corneum of epidermal layer of skin, the quantitative and qualitative changes in lipid composition could result in diminished antibacterial activity(Ohnishi et al.,1999).

Otolaryngeal examination of our studied subjects revealed only two cases with perforated nasal septum and nine cases (18%), with history of repeated epistaxis. This is consistant with data published by Sunderman (1993), who reported that workers in nickel refineries and nickel electroplating shops, exposed to nickel dusts and aerosols of soluble nickel compounds, frequently developed chronic hypertrophic rhinitis and nasal sinusitis. Associated findings were anosmia, nasal polyposis and perforation of the nasal septum. Chronic pulmonary irritation has also been reported. Periodic screening for nasal cancer should be carried out routinely among workers exposed to nickel salts.

The effects of nickel exposure on pulmonary function have been investigated in nickel smelter workers (Broder et al.,1989) and in stainless steel welders (Kilburn et al.,(1990)). In both groups of workers, no differences in pulmonary function were observed during cross-shift or short-term (one week) exposures. Reduced vital capacities and flows were observed in long-term (11 years) workers exposed to welding gases and fumes; however, the authors noted that "there is little evidence for adverse chronic effects on pulmonary function caused by nickel." With respect to spirometric results of the studied population in our work, reduction of all ventilatory fucntion was observed among nickel-electroplating workers but when compared to the control subjects, the difference was not statistically significant.

Haley and his colleagues (1990) conducted an experimental study for demonstrating the immunotoxicity of three nickel compounds given by inhalation in mouse. Their results indicated that inhalation exposure to nickel can result in immunosuppression, increased susceptibility to respiratory infections and immunological hyperactivity characterised by either nickel-induced hypersensitivity or possibly asthma. This effect on the immune system was depending on dose and physicochemical form of the nickel compound. Our study demonstrated this immunotoxic effect by a statistically significantly lower level of IgA among exposed workers compared to the control workers. Hypersensitivity encountered in our workers in the form of asthma and allergic dermatitis was explained by the significantly higher levels of IgE among the exposed workers than among the controls. Similarly Krezel (Krezel et al.,2003) explained simular fundings through demonstrating the correlations between complexation modes and redox activities of Ni(II)–GSH complexes.

The literature since 1985 on the biological monitoring of occupational, environmental, or iatrogenic exposures of humans to nickel is surveyed from the author's perspective. Urine and serum are the body fluids commonly analyzed for nickel (Sanderman et al.,1986). Measurements of nickel concentrations in body fluids especially urine (Ni-U)and serum (Ni-S), provide meaningful insights into the extent of nickel exposures. The presence of high values should be a warning signal to reduce exposure. Absence of high value does not necessarily indicate freedom from health risks (e.g cancers of the lung and nasal cavities) associated with exposure to certain relatively insoluble nickel compounds (Sunderman , (1993). The results obtained by Oberdorster (Oberdorster et al.,2005) suggested that Ni-U is a sufficiently sensitive indicator for use in monitoring low-level occupational exposure, especially if Ni-A concentrations are above 10 micrograms/ m3 which is the current TLV-TWA.

We measured urinary nickel (Ni-U) and serum nickel (Ni-S) as biological indicators to assess exposure to soluble nickel compounds in the electroplating workshop. Statistically significantly higher mean values of Ni-U and Ni-S were found in the exposed workers compared to the referent group.
We observed consistent correlation between the breathing zone nickel concentrations and both serum and urinary nickel concentrations. Our study demonstrated a statistically positive significant relation between the level of both Ni-S and Ni-U and the level of serum creatinine, retinol binding protein and IgE. The level of IgA showed a statistically negative correlation with Ni-S and Ni-U, explaining the higher tendency of recurrent chest infection among nickel-palting workers compared to the controls, in our study.
Conclusion: Nickel used in electroplating is a potential cause of occupational asthma. Occupational asthma was diagnosed in 44% among electroplaters.Inhalation challenge with nebulised potassium dichromate solution is helpful in making the specific diagnosis where doubt exists. Nearly two thirds of the exposed group were suffering from chronic bronchitis who were mostly colonized by *Staphylococcus aureus, Streptococcus pneumonia*. High prevalence of nickel dermatitis (58%) was demonstrated among the exposed workers. Low IgA and high IgE might be the explanation for the detected clinical manifestations.
Recommendations

Environmental measures complying with the OSHA regulations, including exhaust ventillation, enclosure should be implemented at the work place. Periodic medical examination including chest and nasal x-rays should be performed annually. Nickel concentration in plasma and urine are helpful for screening and it is recommended that the tentative biologic TLV of nickel in urine be considered as 150 Ug/L. (Doull et al.,1988). In suffering cases sputum and skin microbial profile should be estimated. We recommend the use of chelating agents for those with high serum and urinary nickel levels. Sodium diethyl thiocarbamate is a drug found to chelate nickel and proved to be of importance in cases of allergic dermatitis (Barceloux ,1999). Patients who developed allergic asthma or who were suspected to be at increased risk of developing allergic asthma should be given a validated respiratory disease questionnaire and pulmonary function testing yearly (Aitio ,1984)

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