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Tissue nickel levels and nickel dermatitis*

I. NICKEL IN HAIR

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SUMMARY

The determination of nickel by instrumental neutron activation analysis is presented. The ^{58}Ni (n, p) ^{58}Co reaction and high-resolution gamma spectroscopy were employed in these measurements. The nickel content of human hair was found to be more dependent upon the sex of the donor than upon other parameters. Mean values for males ($1{\cdot}01 \pm 0{\cdot}23$ ppm) and females ($4{\cdot}21 \pm 0{\cdot}54$ ppm) agreed with values for the nickel content of hair obtained by other methods in most cases. Nickel sensitivity was not reflected in the nickel contents of hair in the female.

People are constantly being exposed to nickel, and nickel contact dermatitis has become an important problem in everyday life. In a recent study on the epidemiology of contact dermatitis in North America in 1972, nickel was the most common cause of contact dermatitis (Epidemiology, 1973). Workers are affected in many occupations; in countless others the exposure is the result of environmental contamination. In the general population, women have by far the highest incidence of contact allergy to nickel, and environmental exposure is responsible in a preponderance of cases.

Hair is considered as a minor excretory organ, and its nickel content could possibly serve as a measure of nickel exposure and the degree of nickel sensitivity. The objective of this study was to measure and compare the nickel content of hair from nickel-sensitive patients and from non-sensitive subjects.

Although atomic absorption techniques are capable of submicrogram sensitivity for nickel, wet

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chemical manipulations are frequently required. Using neutron activation analysis, it is possible to carry out nickel determinations with entirely instrumental procedures (hence, the possibilities of loss or contamination are minimal). The determination of nickel by neutron activation analysis is accomplished by either the ^{64}Ni (n, γ) ^{65}Ni reaction or the ^{58}Ni (n, p) ^{58}Co reaction. The former reaction requires radiochemical separation of nickel prior to counting the 2·1 MeVβ from ^{65}Ni (Bowen & Gibbons, 1963). The ^{58}Ni (n, p) ^{58}Co reaction can be made highly selective under proper conditions, and it is suitable for the determination of nickel by instrumental procedures.

The ^{58}Ni (n, p) ^{58}Co reaction has a cross section of 90 mb, and the resulting ^{58}Co decays with a 71 day half life emitting a 811 KeV photon (Lyon, 1964; Lederer, Hollander & Perlman, 1967). Many of the (n, γ) reactions can be inhibited by shielding the sample with cadmium during radioactivation. Cadmium foil of 0·5 mm thickness efficiently absorbs neutrons of less than 0·5 eV, and it has little effect on the (n, p) reactions (Moses, 1964). Hence, samples radioactivated under cadmium foil yield less complex gamma spectra. By careful control of the activation time and cooling period, a high degree of selectivity for nickel can be achieved. The major interference in the gamma spectrum is due to the ^{54}Fe (n, p) ^{54}Mn reaction. The 835 KeV photon from ^{54}Mn, however, is readily distinguished from the 811 KeV photon of ^{58}Co by measurement on a high resolution Ge (Li) detector.

A standard nickel solution containing 100 μg Ni/ml was prepared from Matthey 'Specpure' NiO. Nickel standards for each set of samples were prepared by pipetting dilutions of this solution on to pieces of polyethylene sheet, evaporating to dryness under a heat lamp, and heat sealing the sheets with the NiO residues into small lengths of 'lay-flat' polyethylene tubing.

Hair samples were collected from forty-five subjects (24 male, 21 female; 38 non-sensitive, 7 nickel-sensitive) by cutting with stainless steel scissors. (Nickel sensitivity was established by patch testing with 2·5% aqueous nickel sulphate.) The samples were individually washed in ether and then in demineralized water. The ends were trimmed with plastic scissors to remove possible contamination induced in the initial cutting. Weighed hair samples (500 mg–1g) were sealed in individual lengths of polyethylene tubing. Standards (0·5–5 μg Ni) were similarly sealed in polyethylene tubing. Samples and standards were packed into polyethylene tubes (1 in $\times$ 3 in) lined with cylinders formed from 0·5 mm cadmium sheet. Discs formed from this sheet covered the tops and bottoms of the cylinders.

Radioactivation was carried out in the 270° vertical tube at the side of the core of the 100 KW Consort Reactor Mark II at the University of London Reactor Centre. At this position, the thermal flux is 1×10^{12} n/cm^2 s, and the fast flux is 2×10^{12} n/cm^2 s. The duration of radioactivation was 20–22 h.

Following radioactivation, the samples and standards were allowed to cool for 14 days. During this time, short-lived species decayed to a point where they contributed little to the radioactivity of the sample.

Counting was carried out on a 30 cm^3 Ge (Li) detector having 5% efficiency and 2·1 KeV resolution coupled to a 8192 channel memory unit. Data were transferred to magnetic tape and evaluated by computer at the University of London. The programme included the determination of the 811 KeV photopeak by the Covell (1954) method. Samples and standards were counted for 4096 s live time using the automatic 12-position sample changer at the University of London Reactor Centre.

Hair samples from the 45 subjects were analyzed for nickel by the procedures outlined above. Histographic presentation of the results (Fig. 1) disclosed two distinct sets: one ranging from 0·75 to 1·50 ppm Ni and the other ranging from 3·00 to 5·25 ppm Ni. Mean values were 1·01 (s.d., 0·23) and 4·21 (s.d., 0·54) respectively. Only the sex of the subject could be correlated with this bimodal distribution: males corresponding to the former and females to the latter. No relationships between age, nickel exposure or nickel sensitivity could be established. The hair samples of the seven nickel sensitive subjects, all of whom were female, had a mean value of 4·53 (s.d., 0·46) ppm Ni while hair

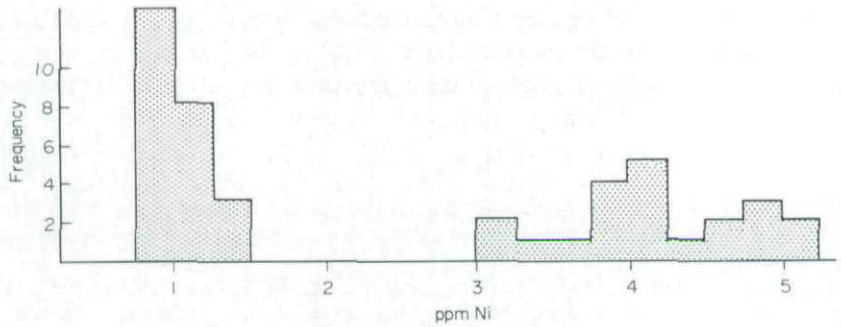

FIGURE 1. Distribution of nickel in human hair.

samples from the non-sensitive female subjects had a mean value of 4·05 (s.d., 0·59) ppm Ni. The Student's t and the probability of the difference between the mean values being due to chance are 1·88 and $>0·05$ respectively. Consequently, there is no significant difference between the mean values, and the nickel content of hair cannot serve as an indicator of the degree of sensitivity.

Significant differences between the nickel contents of hair from the male and that of the female have been reported by Schroeder & Nason (1969). Their analyses were performed by atomic absorption spectrometry, and their sample population was some four times larger than ours. Our mean values tend to be greater than theirs. The difference in nickel content of male and female hair is not as pronounced in the values reported by Eads & Lambdin (1973). They measured the nickel contents of hair samples from ninety-nine subjects by atomic absorption spectrometry and reported higher mean values for males and lower mean values for females than those reported by Schroeder & Nason (1969) and those found by us. Yurachek, Clemena & Harrison (1969) have analyzed human hair by spark source mass spectrometry. They have reported nickel levels for only two samples. While none of these other studies attempted to correlate the nickel contents of hair with nickel sensitivity, they do show mean values in fair agreement with our results. Nechay & Sunderman (1973), however, have reported that there was no significant difference in the nickel content of hair from the male and that from the female. They measured the nickel contents of twenty hair samples (13 male, 7 female) by atomic absorption spectrometry, and they found a mean value of 0·22 ppm Ni (s.d., 0·08 ppm Ni).

Mean values reported by others are compared with our results in Table 1.

From the work of others (Schroeder & Nason, 1969; Eads & Lambdin, 1973; Yurachek *et al.*,

TABLE 1. Nickel levels in human hair according to sex

	Male (ppm)	Female (ppm)
Schroeder & Nason (1969)	0·98 ± 0·15	3·96 ± 1·06
Eads & Lambdin (1973)	1·9	3·4
Yurachek *et al.* (1969)	0·45*	3·4*
Nechay & Sunderman (1973)	0·24 ± 0·009	0·19 ± 0·04
This work		
Nonsensitive subjects	1·01 ± 0·23	4·05 ± 0·59
Nickel-sensitive subjects		4·53 ± 0·46

* Sex of subject not indicated.

1969) as well as from our own measurements, we conclude that there is a significant difference between the nickel content of hair from the human male and that of the female. Furthermore, our work demonstrates that nickel sensitivity is not reflected in the nickel contents of hair in the female.

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