Chapter 6.11 Platinum

General description

Platinum (Pt) is a malleable, silvery white, noble metal widely but sparingly distributed over the earth's crust. It is found mainly as the isotopes with atomic weights of 194, 195 and 196, with a maximum oxidation state of +6, the oxidation states of +2 and +4 being the most stable. While the metal does not corrode in air at any temperature, it can be affected by halogens, cyanides, sulfur, molten sulfur compounds, heavy metals and hydroxides. The chemistry of platinum compounds is dominated by the coordination complexes, hexachloroplatinic acid, potassium and ammonium tetrachloroplatinate, potassium, sodium and ammonium hexachloroplatinate, and *cis*- and *trans*-diamminedichloroplatinum. Also important are the binary compounds of platinum, the chlorides (+2 and +4), the oxide, and also the sulfate and nitrate.

Analytical methods for platinum have been reviewed *(1)*. Neutron activation analysis is a sensitive method for the detection of platinum in plants, rocks and soils. Atomic absorption spectrometry (AAS) is highly selective and specific, but an accurate separation from the matrix is essential. The method has been used for the determination of platinum in particulate emissions from motor vehicle catalytic converters in test stand experiments. Inductively coupled plasma-mass spectrometry enables platinum determination to the pg/ml range, and has been recommended for analysis of stream sediment, rock and soil samples. The determination of platinum in biological samples was unreliable before the 1980s, levels being below the detection limits of the methods then in use. More recently, voltammetry has been used to monitor platinum in blood and urine, and it has been suggested that this is the only reliable method for the collection of baseline data on blood levels in unexposed subjects, these being within the low ng/litre range *(2)*. The reliability of voltammetry has been demonstrated for the determination of platinum in airborne dust *(3)*.

Sources

Platinum, together with the other platinum group metals, is present at low levels in the lithosphere, with an average platinum concentration of 0.001–0.005 mg/kg *(4)*. Concentrates of economic importance are present in the Transvaal, South Africa, in Siberia and in the Urals at up to 500 mg/kg, and in Sudbury, Canada, in copper-nickel sulfide ores at an average concentration of 0.3 mg/kg. The world production of platinum group metals has increased steadily over the past two decades, with a total of 127 tonnes in 1971 rising to 270 tonnes (with 108–135 tonnes of platinum) in 1987 *(5)* and 152 tonnes in 1995. Further increases are predicted, in part attributable to a growth in the use of catalytic converters for motor vehicle exhausts.

Platinum has exceptional catalytic properties and is used in the chemical and petroleum industries in hydrogenation, isomerization, cyclization, dehydration, dehalogenation and oxidation reactions. Major uses are in ammonia oxidation, in the production of nitric acid and in the catalytic upgrading of the octane rating of gasoline. A motor vehicle catalytic converter

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contains 1–3 g of platinum. Catalytic converters were introduced in 1975 in the United States to meet the stringent emission limits of the Federal Clean Air Act, and became mandatory in the European Community in 1993. In the electrical industry, platinum has many high-temperature uses, in platinum resistance thermometers, thermocouples and strain gauges, in electric contacts for relays and switch gears, in electrochemical platinum electrodes and in printed circuits. Platinum is used as a catalyst in fuel cells for the generation of electricity. Its high melting point and resistance to corrosion have led to further uses in laboratory ware, such as crucibles and the tips of tongs, and to protect ships hulls and propellers. Platinum is also used in the glassmaking industry and in the production of fibreglass and in jewellery for rings and settings for gems.

In dentistry and medicine, platinum is used in dental and neurological prostheses, for recording electrical activity, and for pacemaker electrodes. *Cis*-diamminedichloroplatinum, *cis*-platin and carboplatin are being used increasingly in the treatment of testicular and metastatic ovarian tumours and in lung and bladder cancer.

Occurrence in air

The average concentration of platinum in the lithosphere has been estimated to be in the region of 0.001-0.005 mg/kg derived from the ores in the magmatic and sedimentary deposits near the earth's crust *(6)*. Approximately 1400 tonnes of platinum have been mined up to the present. It has been estimated that a daily global influx from meteorites with an average platinum group metal content of 100 mg/kg gives a daily addition of 10 kg of these metals dispersed over the globe over geological time, this being sufficient to give measurable background levels *(7)*.

Anthropogenic sources of platinum have given rise to elevated levels in river sediments in highly industrialized areas. In particular, a high level of pollution has been recorded in sediments of the river Rhine, Germany, with values of 734-31 220 µg/kg dry weight *(8)*.

Few measurements of ambient air concentration prior to the introduction of motor vehicle catalytic converters have been reported. Air samples taken near freeways in California and analysed using AAS were below the detection limit of 0.05 pg/m^3 *(9)*. In rural areas in Germany, at a time when few cars were equipped with catalytic converters, platinum concentrations were <0.6-1.8 pg/m^3, reflecting background levels. Close to city roads in Frankfurt, platinum air concentrations were found to be <1-13 pg/m^3 *(10)*. Catalytic converters have been termed mobile sources of platinum, loss of small quantities of platinum resulting from mechanical and thermal impact. The pellet-type, introduced initially in the United States but never used in Europe, was estimated to emit up to approximately 2 µg of platinum per kilometre travelled. Of the particles emitted, 80% had diameters greater than 125 µm *(11)*. The proportion of the respirable fraction is not known. Emission of platinum from the new generation three-way monolith-type catalytic converter, currently used in the United States and Europe, is lower by a factor of 100-1000 than from the earlier type *(1)*.

Engine test stand experiments have been conducted at the Fraunhofer Institute of Toxicology and Aerosol Research, Germany, within a programme for assessing the relative risk of platinum emission from the monolith type. At a simulated speed of 100 km/hour, the total emission of platinum in the exhaust gas loss measured using AAS was found to average about 17 ng/m^3 *(1,12)*. In further studies involving several test runs and repetitive sampling of platinum emissions from two catalysts, particulate emission concentrations were in the range 3-40 ng/m^3, corresponding to emission rates of about 2-40 ng/km *(13)*. Platinum emissions were observed to increase with speed and with increasing exhaust gas temperature. In this study, with the

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exception of one measurement, all platinum mass median aerodynamic diameters were greater than 5 μm. The particle size of platinum concentrated in urban dust was found to be 0.58-8 μm *(14)*. Platinum emitted from petrol engines showed a photoemission spectrum indicating that it is probably emitted mostly in the form of surface-oxidized particles. In diesel engine exhaust, the majority was in the form of platinum black, oxidation state O, with a small proportion as platinum(IV) and probably in the oxide form.

In addition to the vehicle catalytic converter, variable amounts of platinum are emitted into the environment, but not directly into air, from other sources. Of the stationary catalysts used by the chemical industry, only those employed for ammonia oxidation emit major amounts. Much of the emitted platinum is recovered, although in one study fertilizers were found to contain 0.3-30 μg/kg *(15)*.

Data on emissions from the electrical and electronics industries are not available but emissions are likely to be small owing to recycling. Similarly emissions from the glass industry and from dentistry are likely to be small. Emissions resulting from medical uses are restricted to the anticancer agents *cis*-platin, carboplatin and iproplatin. These drugs are excreted into the urine and subsequently released into the environment via the sewage system. Nearly all the administered dose, estimated to amount to some 30 kg per annum is likely to end up in sewage works, bound to proteinaceous matter with subsequent degradation resulting in removal of the platinum as a sulfide in sewage sludge (P.J. Owen, personal communication, 1994).

The concentrations of platinum in air will in part be reflected in dust fall measurements. In a detailed study of roadside dust and stream sediment concentrations of platinum in Sweden, an increase in roadside dust concentration of platinum was observed from 1984 to 1991, while over the same period the concentration of lead in the same samples had decreased *(16)*. Over this period the fraction of particles with a diameter of less than 63 μm showed the highest increase, from 3.0 to 8.9 ng/g.

In summary, in 1989 when few cars were equipped with catalytic converters, background levels of particulate matter in air close to city roads in Frankfurt were <1-13 pg/m^3, whereas those in rural areas were <0.6-1.8 pg/m^3, probably reflecting background concentrations *(10)*. In a study of airborne dust in Dortmund the platinum content ranged from 0.6 to 130 ng/g and that in air from 0.02 to 5.1 pg/m^3 *(14)*. This study employed the more sensitive method of voltammetry and should be considered more reliable. Some 30-40% of the platinum found in the airborne dust was soluble in dilute hydrochloric acid, compared to only 2.5-6.9% of that found in a dust sample collected in a traffic tunnel. The authors attributed this significant difference to the different origin of the platinum in the two samples. Values for air have been quoted in the range 0.3-30.0 pg/m^3, the higher figures probably resulting from pollution *(15)*.

Routes of exposure

Air

Assuming values for platinum levels of 0.3-30 pg/m^3 and a daily inhalation of 20 m^3 of air, the average daily intake of platinum via inhalation would range between 6 pg and 600 pg. This is likely to be an overestimate.

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Food
A study of platinum levels in the diet was conducted in 1986 on market-basket samples in Sydney, Australia *(17)*. Foods were prepared using normal cooking procedures, then either blended and air-dried or lyophilized, analysis being carried out by adsorptive voltammetry. Platinum concentrations were highest in eggs and offal, with a mean concentration of 5.8 ng/g, followed, in decreasing order, by meat (3.2 ng/g), grain products (3.2 ng/g), fish (1.8 ng/g), fruit and vegetables (0.82 ng/g) and dairy products (0.27 ng/g). Using hypothetical diets compiled by the Australian Federal Department of Health, the platinum intake from the diet was calculated to be of the order of 1.44 µg/day for adults. Food samples were also analysed from Lord Howe Island in the South Pacific, an island with few cars and little pollution; similar platinum levels were found.

Water
Platinum levels in drinking-water have been estimated at 100 pg/litre, with a similar value in glacier ice *(15)*. However, the very high level reported for platinum in tap-water from Liverpool, at 60 000 pg/litre, requires further investigation *(18)*. The same investigators have reported platinum levels ranging from 37 to 154 pg/litre for water samples from the Indian Ocean. Platinum levels of the order of 100-200 pg/litre have been reported from the Pacific Ocean *(19)* and a level of 2200 pg/litre for waters from the Baltic Sea. In filtered samples from the Pacific, platinum levels have been shown to increase with depth, showing nutrient-like profiles *(20)*.

Relative significance of different routes of exposure
The major pathway of platinum into the human body at the population level is via the diet, with an average dietary intake of 1.44 µg/day for all adults, 1.73 µg/day for males and 1.15 µg/day for females *(17)*.

The highest levels of exposure to platinum have occurred in occupationally exposed workers via inhalation and in patients treated with platinum-based chemotherapeutic agents by intravenous injection. With regard to occupational exposure, the time-weighted average threshold limit value (TWA-TLV) is 2 µg/m^3 for soluble platinum salts and 1 mg/m^3 for platinum metal *(21)*. In the United Kingdom, an occupational exposure limit (8-hour TWA) of 5 mg/m^3 has been proposed for platinum metal as total inhalable dust and a limit of 2 µg/m^3 for platinum in platinum salts *(22)*. In early studies on occupationally exposed workers, estimated workplace levels ranged from 0.9 to 1700 µg/m^3, levels that gave rise to serious adverse effects (see below) *(23)*. Levels of platinum in urine from patients treated with *cis*-platin are high, and reported values have ranged from 4100 to 11 300 µg/litre.

Toxicokinetics

Reported platinum concentrations in body fluids and tissues, in particular those dating from the 1970s, should be treated with caution because of questionable analytical reliability. Background levels of platinum in human blood from Australia were reported to be in the range 0.1-2.8 µg/litre, mean 0.6 µg/litre *(24)*. In contrast, whole-blood levels in a German study *(25)* were reported to be in the range 0.8-6.9 ng/litre. Adsorptive voltammetry was used for the analysis in both studies. In the German study, platinum-exposed workers showed whole-blood levels of 0.032-0.180 µg/litre. An interlaboratory comparison of platinum determinations in body fluids is urgently required. Data on platinum levels in autopsied tissue samples date back to the 1970s. In two studies platinum levels were below the limit of detection. In a third study, of 1313 samples, only 5% had detectable levels of platinum ranging from 3.0 to 1460 µg/kg wet weight, mean 160 µg/kg. The frequency of occurrence, taken as a measure of the distribution of platinum

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among the various body organs, centred on subcutaneous fat, kidney, pancreas and liver *(26)*. A single study on platinum levels in human hair found a concentration range of 0.87-18.31 ng/g in male and female unexposed Sidney residents *(17)*.

Toxicokinetic data have been derived mainly from studies on rats and mice using platinum complexes. Whole-body retention, lung clearance, distribution and excretion of platinum-191 was studied in albino rats following inhalation exposure. Whole-body counts showed that most of the inhaled platinum was rapidly cleared from the body, followed by a slower clearance phase. Lung clearance was also biphasic, a fast clearance phase in the first 24 hours being followed by a slow phase with a half-life of about 8 days *(27)*. Excretion data from this study showed that most of the inhaled platinum was cleared by mucociliary action, swallowed and excreted via the faeces with a small fraction excreted in the urine, indicating that little had been absorbed by the lungs or gastrointestinal tract. Highest levels of radioactivity were found in kidney and bone, suggesting some accumulation in these tissues. In a long-term study in which rats were fed platinum salts *ad libitum* in drinking-water and dry feed, accumulation of platinum occurred primarily in the kidney, where it was about 8-fold higher than in liver or spleen and 16-fold higher than in blood *(28)*. In contrast, when insoluble platinum oxide was given, only minute amounts were absorbed even though administered at a very high level. In this study, there was suggestive evidence of the induction of a platinum-binding protein.

The diammine complexes of platinum, such as *cis*-platin, are excreted mainly in the urine, as shown in mice, rats and dogs *(29)*. The excretion of both the *cis*- and *trans*- forms follows a biphasic pattern. The extremely rapid initial phase accounts for early high levels of platinum in kidney, liver and other tissues, the prolonged second phase results in detectable urine platinum concentrations 30 days after a single dose. These experimental studies have been reviewed in greater detail *(1)*.

Health effects

Effects on experimental animals

Toxicological effects
The acute toxic effects of platinum are dependent on metal speciation, soluble compounds being very much more toxic, in particular the coordination complexes. Ammonium tetrachloroplatinate has been reported to induce acute poisoning in rats, with hypokinesia, diarrhoea, convulsions and respiratory impairment *(30),* while hexachloroplatinic acid is highly nephrotoxic, again in the rat *(31)*. In contrast, metallic platinum orally administered to rats as fine particles produced minor necrotic changes in the gastrointestinal epithelium and swelling of the epithelium of the convoluted renal tubules, with no lethal effect *(1)*. Alloys containing metallic platinum have been used in prostheses. All tested platinum compounds have shown eye irritation, ammonium tetrachloroplatinate was found to be corrosive and a number of compounds have caused skin irritation in albino rabbits. In cynomolgus monkeys, nasal inhalation of sodium hexachloroplatinate caused pulmonary deficits compared with controls, while ammonium hexachloroplatinate produced pulmonary hyperreactivity and skin hypersensitivity but only with concomitant exposure to ozone *(32)*. Attempted sensitization in rats, guinea pigs and rabbits has given conflicting results *(1)*.

A number of platinum compounds have been found to be mutagenic in bacterial systems, in particular, *cis*-platin showed the highest mutagenic potential. Potassium tetrachloroplatinate and

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tetra-ammine platinum chloride showed no evidence of mutagenic activity, other platinum compounds showed intermediate levels of activity.

Studies on animals, including reproductive toxicity, and on mutagenicity have been reviewed *(1)*.

There are no experimental data on the carcinogenic activity of platinum and its compounds with the exception of *cis*-platin, for which there is sufficient evidence for carcinogenic activity in animals; it has been shown to significantly increase lung adenoma frequency, to induce skin papilloma and carcinoma in mice and leukaemia in rats. *Cis*-platin was classified by IARC as a group 2A carcinogen, i.e. sufficient evidence for carcinogenicity in animals but inadequate evidence in humans. *Cis*-platin produces specific inhibition of DNA synthesis. DNA cross-links appear to be responsible for cellular toxicity but intrastrand cross-linking formed only by the *cis*-isomer at a certain position of guanine is considered to be the mechanism for its antitumour activity *(1)*. Structural chromosomal aberrations and sister chromatid exchanges have been observed in cells of rodents treated *in vivo*.

Effects on humans

Toxicological effects
The toxicological effects of platinum in humans are confined to certain of its complex halide salts and to the antitumour agent *cis*-platin and its analogues. The adverse health effects of the halide salt complexes are characterized by sensitization; these compounds are among the most potent sensitizers known. Such sensitization has been reported almost exclusively from occupational environments. An initial report in 1911 described irritation of the nose and throat with difficulty in breathing in workers in a photographic studio handling paper treated with complex platinum salts. In a study in four British refineries, 52 of 91 workers exposed to complex platinum salts exhibited repeated sneezing, rhinorrhoea, chest tightness, wheezing, shortness of breath and cyanosis, while a proportion of these also developed scaly erythematous dermatitis with urticaria *(23)*.

Subsequent studies have shown a similar pattern following occupational exposure to complex platinum salts, and symptomatology can be summarized as including watering of the eyes, sneezing, rhinorrhoea, cough, wheeze, dyspnoea and cyanosis characteristic of severe asthma, itching, contact dermatitis and urticaria. The condition has been termed platinum salt hypersensitivity. The latent interval from initial contact with platinum to the development of symptoms has varied from a few weeks to several years, symptoms worsening with increasing length and intensity of exposure and initially clearing following removal from exposure, but with a tendency to persist following longer exposure periods. Once sensitization has developed, subsequent exposures to minute concentrations of the platinum salt have elicited both immediate and late-onset reactions.

Platinum allergy appears to be induced by a group of charged compounds with reactive ligand systems, the most potent being hexachloroplatinic acid and the chlorinated salts ammonium hexachloroplatinate, potassium tetrachloroplatinate, potassium hexachloroplatinate and sodium tetrachloroplatinate. Non-halogenated and neutral complexes have been shown to be non-allergenic. The mechanism of platinum salt allergy is likely to be a type l, immunoglobulin IgE-mediated response, platinum salts of low relative molecular mass acting as haptens which combine with serum proteins to form the complete antigen *(33)*. Skin-prick tests with

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ammonium and sodium hexachloroplatinate and with sodium tetrachloroplatinate provide specific and sensitive indicators of an allergic state and are used routinely in monitoring platinum workers. Following sensitization, skin-prick tests with concentrations of these platinum compounds as low as 10^{-9} g/ml have produced immediate weal and flare reactions in highly sensitized individuals, but reactions have not been seen in atopic or non-atopic controls *(34)*. Nasal instillation giving rise to sneezing or rhinorrhoea, and inhalation with a mixture of ammonium hexachloroplatinate and lactose dust giving rise to both immediate and late asthmatic reactions have also been used in testing for platinum salt hypersensitivity.

The sensitivity and reliability of the skin-prick test has not been equalled by any other test, the *in vitro* radioallergosorbent test and tests for histamine release being too nonspecific to be used for screening purposes. There is limited evidence to suggest that bronchial hyper-responsiveness as shown by the cold air challenge test may precede evidence of cutaneous sensitization in platinum-exposed workers *(35)*. While atopy does not appear to be a significant predisposing factor, tobacco smoking has been shown to increase the risk of sensitization in platinum-exposed workers *(36)*.

While extensive studies have been performed regarding a hypersensitive response in platinum-exposed workers who are currently routinely monitored, very little attention has been paid to possible effects of exposure to platinum emitted into the general environment from motor vehicle catalysts. In one small study, which has been extensively quoted, three subjects highly sensitive to platinum salt at low concentrations as evinced by a positive skin-prick test were tested with particulate exhaust samples. The total platinum content at the highest concentration exceeded 5 µg/ml, which would normally be sufficient to elicit a response. Five extracts at different concentrations did not elicit a positive response on the skin-prick test in the three subjects *(37)*. This observation is compatible with what is currently known regarding the speciation of emitted platinum. As stated in an earlier publication *(1)*, since the emitted platinum is most probably in the metallic form, the sensitizing potential of platinum emissions from automotive catalysts is probably very low. No information is available on the possible environmental conversion of emitted platinum to complex halide salts.

In contrast to the halogenated platinum salts, *cis*-platin used in cancer chemotherapy has given rise to nephrotoxicity with both tubular and glomerular lesions, severe nausea and vomiting, ototoxicity with tinnitus and hearing loss, and sensory peripheral neuropathy. While carboplatin is less nephrotoxic, it has induced bone marrow suppression *(38)*.

There are no data available to assess the carcinogenic risk of platinum or its compounds in humans, and no recent epidemiological studies of cancer incidence or mortality in platinum workers have been reported *(39)*.

Evaluation of human health risks

Exposure evaluation

There is currently very little information on levels of exposure to soluble platinum compounds in the general environment and there are no authenticated observations on adverse health effects in the population resulting from such exposure. Examples of the limited available data derived from air sampling and from dust deposition of total platinum have been given above. Ambient air concentrations of platinum compounds that would occur in different scenarios have been

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estimated using dispersion models developed by the US Environmental Protection Agency *(40)*. Ambient air concentrations of total platinum in various urban exposure situations, assuming an average emission rate of approximately 20 ng/km from the monolithic three-way catalyst, are shown in Table 1. These concentrations are lower by a factor of 100 than those estimated for the old, pellet-type catalyst. In the exposure conditions tabulated, estimated ambient air concentrations of platinum range from 0.05 pg/m^3 to 0.09 ng/m^3. The WHO Task Group on Environmental Health Criteria for Platinum considered that environmental contamination with platinum from the monolithic three-way catalyst is likely to be very low or negligible *(1)*. The Group concluded that platinum-containing exhaust emissions from such catalysts most probably do not pose a risk for adverse health effects in the general population but it was recommended that, to be on the safe side, the possibility should be kept under review.

Table 1. Estimated ambient air concentrations of total platinum in various exposure situations, assuming an average emission rate for vehicle catalytic converters of approximately 20 ng/km

Exposure situation	Platinum concentration (ng/m^3)
Road tunnel	
Typical	0.04
Severe	0.09
Street canyon (sidewalk receptor)	
Typical, 800 vehicles/hour	0.001
Typical, 1600 vehicles/hour	0.003
Severe, 1200 vehicles/hour	0.005
Severe, 2400 vehicles/hour	0.009
On expressway	
Typical	0.007
Severe	0.016
Near expressway (short-term)	
Severe 1 m	0.013
10 m	0.011
100 m	0.003
1000 m	0.0004
Near expressway (annual)	
Severe 1 m	0.002
10 m	0.0015
100 m	0.0004
1000 m	0.00005

Source: World Health Organization *(1)*.

A recently completed pilot study sought to acquire information on direct and indirect sources and emissions of platinum group metals in the United Kingdom environment *(41)*. With regard to emissions from motor vehicle catalytic converters, samples of road dusts and soils were collected from areas with high and low traffic flows, for platinum and lead estimation. Higher levels of platinum were found in dusts and soils at major road intersections and on roads with high traffic densities, indicating traffic as the source of platinum at these sites *(42)*.

As platinum in road dust is at least partially soluble, it may enter the food-chain so that diet may also be a major source of platinum intake in the non-industrially exposed population. This is suggested by the total diet study carried out in Australia in Sydney, an area of high traffic density, and Lord Howe Island, an area with very low traffic density. Blood platinum levels were similar in the two locations *(17)*.

In early studies on platinum-exposed workers, exposure levels were high. Values ranged from 0.9 to 1700 μg/m^3 in four British platinum refineries, giving rise to symptoms in 57% of the

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exposed workers *(23)*. Following the adoption of an occupational exposure limit with a threshold limit value (TLV) for soluble platinum salts of 2 μg/m^3 as an 8-hour time-weighted average (TWA), the incidence of platinum salt hypersensitivity has fallen, but sensitization in workers has still been observed. Thus, in a cross-sectional survey, skin sensitization was reported in 19% of 65 workers in a platinum refinery, where analysis of airborne dust showed levels of soluble platinum of 0.08-0.1 μg/m^3 in one department and less than 0.05 μg/m^3 in other areas *(43)*. In another plant with air levels generally below 0.08 μg/m^3, 20% of exposed workers were sensitized *(44)*. It is possible, however, that short, sharp exposures to concentrations above the TLV could have been responsible for some of these effects. In a 4-month study in a United States platinum refinery with a high prevalence of rhinitis and asthma, workplace concentrations exceeded the occupational limit of 2 μg/m^3 for 50-75% of the time *(36)*. The risk of developing platinum salt sensitivity appears to be correlated to exposure intensity, the highest incidence occurring in groups with the highest exposure, although no unequivocal concentration-effect relationship can be deduced from the reported studies.

Health risk evaluation

There is no convincing evidence for sensitization or for other adverse health effects following exposure to metallic platinum. Exposure to the halogenated platinum complexes already described has given rise to sensitization following occupational exposure to platinum concentrations in air greater than the TLV of 2 μg/m^3, and may have caused sensitization reactions at concentrations down to and even below the limit of detection in workplace monitoring of 0.05 μg/m^3. Furthermore, as subsequent exposure to minute concentrations of these platinum salts may lead to a recurrence of the health effects shown in Table 2 in previously sensitized subjects, it is not possible to define a no-effect level for these platinum compounds.

Because the correlation between platinum exposure concentration and the development of sensitization is unknown, the WHO Task Group *(1)* considered that a recommendation for a reduction in the occupational exposure limit cannot at present be justified. It did, however, recommend that the occupational exposure limit of 2 μg/m^3 be changed from an 8-hour TWA to a ceiling value, and that personal sampling devices be used in conjunction with area sampling to

Table 2. Concentration–effect data for platinum

Concentration range	Average duration of exposure	Frequency of health effects in the general population	Health effects in susceptible groups
Airborne dust level for soluble platinum salts above the TLV time-weighted average of 2 μg/m^3	Varies from weeks to years	No data available	In some occupationally exposed individuals: conjunctivitis, rhinitis, cough, wheeze, dyspnoea, asthma, contact dermatitis, urticaria, mucous membrane inflammation
Airborne dust level for soluble platinum salts < 0.05 μg/m^3			Possibility that the above effects cannot be excluded Recurrence of the above effects in subjects previously sensitized

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	Conversion to positive skin-prick test

determine more correctly the true platinum exposure. Should it be ascertained unequivocally that sensitization has occurred in workers consistently exposed to platinum levels below the current exposure limit of 2 μg/m^3, and that intermittent, short exposures above this level had not taken place, there would be strong grounds for reducing the exposure limit.

The degree of solubilization and perhaps conversion to halide complexes of platinum particulate matter emitted into the general environment is not known, but is likely to be small. The prevalence of asthma in industrialized communities is increasing markedly, and while there are no observations to suggest that platinum (emitted from vehicle catalytic converters or from industrial sources, deposited and in part converted in the general environment into halide salts) may act as an etiological agent, it would be inappropriate in the present state of knowledge to propose a no-effect level. From observations following occupational exposure, a value of 0.05 μg/m^3 for soluble platinum salts may be considered as a tentative lowest-observed-adverse-effect level (LOAEL). Platinum levels in air in the general environment are at least three orders of magnitude below this figure.

While *cis*-platin, an IARC group 2A carcinogen, is released into the environment following medical use, there are no grounds for considering this platinum compound or its analogues as significant atmospheric pollutants.

Guidelines

In occupational settings, sensitization reactions have been observed for soluble platinum down to the limit of detection of 0.05 μg/m^3. However, these effects have only occurred in individuals previously sensitized by higher exposure levels. It is unlikely that the general population exposed to ambient concentrations of soluble platinum, which are at least three orders of magnitude lower, will develop similar effects. At present no specific guideline value is recommended but further studies are required, in particular on the speciation of platinum in the environment.

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