Palabora Copper (Pty) Limited

Material Safety Data Sheet	Nickel Sulphate

SUPPLIER DETAILS

Supplier Name:	**Palabora Copper (Pty) Limited**	**Emergency Telephone Number:**	**+27 (0)15 780 2666**
Address:	**PO Box 65 1 Copper Road Phalaborwa 1390 South Africa**	**E-Mail Address:**	palabora.msds@palabora.co.za
		Telephone Number:	**+27 (0)15 780 2281**
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Person Responsible for Updating MSDS:	**Manager: Environment & SHEQ MS**	**URL / WebPages:**	**http://www.palabora.com/**

1. PRODUCT IDENTIFICATION

Chemical Names and Synonyms: Nickel (II) Sulphate Hexahydrate, NiSO4.6H2O	**UN Number: 3077**
CAS Number: 10101-97-0	**NIOSH Number: /**

2. COMPOSITION

Nickel (II) Sulphate hexahydrate - 95%

CAS Number:	10101-97-0
Molar Mass:	262.86
Molecular Formula:	NiSO4.6H2O
EC-Index Number:	028-009-00-5
EC-Number:	232-104-9

3. HAZARDOUS IDENTIFICATION

HAZARD CLASSIFICATION & LABELING: Human Health and Environment			
ENDPOINT	**GHS**		
	CLASSIFICATION		**M-Factor**
	Hazard Class & Category Code	**Hazard Statement Code**	
Dermal Irritation/Skin Corrosion (GHS)	Skin Irrit. 2	H315	**M = 1**
Dermal Sensitization	Skin Sens. 1	H317	
Mutagenicity	Muta. 2	H341	
Acute Oral Toxicity	Acute Tox. 4	H302	
Acute Inhalation Toxicity	Acute Tox. 4	H332	
Chronic Toxicity/STOT-RE (inhalation)	STOT RE 1	H372	
Reproductive Toxicity	Repr. 1B	H360D	
Carcinogenicity (inhalation)	Carc. 1A	H350i	
Respiratory Sensitization	Resp. Sens. 1	H334	
Acute Aquatic Environment	Aquatic Acute 1	H400	
Chronic Aquatic Environment	Aquatic Chronic 1	H410	

4. FIRST AID MEASURES

Inhalation - Fresh air. Seek medical attention

Skin Contact - Remove contaminated clothing including shoes. Wash affected area with plenty of soap and water for at least 20 minutes.

Eye Contact - Rinse out with plenty of water with the eyelid held wide open. Seek medical attention.

Ingestion - Large quantities of water should be drunk. Seek medical attention.

Wounds - Cleanse thoroughly to remove any nickel sulphate particles.

5. FIRE FIGHTING MEASURES

Special Risks - Non-combustible. Development of hazardous combustion gases or vapours possible in the event of fire. The following may be present in the event of fire. Sulphur Oxides

Special Protective Equipment for Fire Fighting - Do not stay in dangerous zone without suitable chemical protection clothing and self-contained breathing apparatus.

Other Information - Contain escaping vapours with water. Prevent fire-fighting water from entering surface water or groundwater

Suitable Extinguishing Media - Adapt to materials stored in the immediate vicinity.

6. ACCIDENTAL RELEASE MEASURES

Person-related precautionary measures:
Avoid substance contact.
Avoid generation of dusts.
Do not inhale dusts.

Environment protection measures: Do not allow to enter aquatic system.

Procedures for cleaning/absorption:
Pick up dry - Collect spills by sweeping or vacuuming with the vacuum exhaust passing through a high efficiency particulate arresting filter if exhaust is discharged into the work place. Avoid generation of dusts.
Dispose of spills in accordance with local regulations.
Clean up affected area.

7. HANDLING AND STORAGE

Keep in the container supplied and keep container closed when not in use. Wear appropriate protective clothing, including waterproof gloves and nationally approved respirators.

Follow local regulations regarding the storage of this material.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

The following ***source*** of information on Occupational Exposure Limits from Member States is the OSHA (European Agency for Safety and Health at work) website: http://osha.europa.eu/en/topics/ds/oel/index.stm/members.stm

The following current national limit values for Nickel and its compounds (November 2010)

Area	**Country**	**Current OELs (mg Ni / m^3)**				
		Soluble	**Metallic**	**Nickel oxide and carbonate**	**Insoluble**	**Nickel Carbonyl (liquid) as $Ni(CO)_4$**
Europe	Finland	0.1	1	0.1	0.1	0.007 (0.021 STEL) (both as $Ni(CO)_4$)
	Norway	0.05	0.05	-	0.05	0.007 (as $Ni(CO)_4$)
	UK	0.1 (MEL$^{\#}$)	0.5 (MEL$^{\#}$)	-	0.5	0.24 (STEL, as Ni)
	France	0.1	1 (VME)*	1	1	0.12 (as Ni)
	Germany	No legally binding OEL currently in place				
	Belgium	0.1	1	-	0.2**	0.12 (as Ni)
	Denmark	0.01	0.05	-	0.05	0.007 (as $Ni(CO)_4$)
	Italy	0. 1	1	-	1	0.12 (as Ni)
Non-Europe	USA (OSHA)	1	1	-	1	0.007 (as $Ni(CO)_4$)
	USA - ACGIH (TLV) *Non-enforceable standard*	0.1$^{\#}$	1.5$^{\#}$	-	0.2**$^{\#}$	0.12 (as Ni) and 0.35 as $Ni(CO)_4$
	Canada - most jurisdictions	0.1	1.5	-	0.2**#	0.35 (as $Ni(CO)_4$)
	Canada - Ontario	0.1	1	-	0.2**$^{\#}$	0.35 (as $Ni(CO)_4$)
	Canada - BC	0.05	0.05	-	0.05	0.007 (as $Ni(CO)_4$)
	Canada - Qc, NT, NU, YT	0.1	1	-	1	0.35 (as $Ni(CO)_4$)
	Japan	0.1	-	0.1	0.1	0.007 (as $Ni(CO)_4$)
	Australia	0.1	1	-	1$^{\$}$	0.12 (as Ni)
	South Africa	0.1	0.5	-	0.5**	0.24 (STEL, as Ni)

*VME = Valeur Moyenne d'Exposition. The value of 1 mg/rn^3 applies to nickel carbonate, dihydroxide, subsulfide, monoxide, sulphide trioxide and for other chemical forms not otherwise specified, such as "insoluble nickel compounds" and nickel sulfide roasting fume and dust.
** For nickel subsulfide the value is 0.1 mg Ni/m^3 as inhalable.
$^{\#}$ Inhalable
$^{\$}$ Nickel sulphides roasting fumes only

MEL	Maximum Exposure Limit
STEL	Short term exposure level
OEL	Occupational exposure limit

TWA	Time-weighted average exposure
TLV	Threshold Limit Value

Personal Protective Equipment:
Respiratory protection - Required when dust is generated
Eye Protection - Required
Hand Protection - Required

Industrial Hygiene:
Protective clothing should be selected specifically for the working place, depending on the concentration and quantity of the hazardous substances handled. Avoid repeated skin and eye contact. Wear goggles or face shield. Wear suitable protective clothing and waterproof gloves. Wash skin thoroughly after handling and before eating, drinking or smoking. Launder clothing and gloves as needed. Application of skin-protective barrier cream is recommended.

9. PHYSICAL AND CHEMICAL PROPERTIES

Form: Crystals
Colour: Green
Odour: Odourless
Formula: NiSO4.6H2O

pH value @ 100g/l H2O, 20 deg C 4.3 - 4.7

Melting temperature 53 deg C (loss of water of crystallisation on heating) Boiling temperature not applicable
Ignition temperature not applicable
Flash point not applicable
Explosion limit Non-explosive
Relative vapour density not applicable

Relative density @ 20 deg C 2.07 g/cm^3
Bulk Density ± 1000 kg/m3

Solubility in
water @ 20 deg C 625 g/l
water @ 100 deg C 3407 g/l

Thermal decomposition > 700 deg C

10. STABILITY AND REACTIVITY

Conditions to be avoided: Strong Heating

Substances to be avoided: Strong Acids

Hazardous decomposition products: In the event of fire - toxic vapours (Sulphur Oxides)

Further Information: Releasing water of crystallization - when heated.

11. TOXICOLOGICAL INFORMATION

Toxicity endpoints	Description of effects
Absorption	ORAL = 30% from food during fasting; 5% from absorption of nickel from food, soil, dust and from water consumed with food [*In vivo* rat, human study and modeling of human data] (Ishimatsu et al., 1995; Sunderman *et al*., 1989; Nielsen et al., 1999; Diamond et al.,1998; EURA, 2008-2009) DERMAL = 2% [*In vivo* human skin stripping and *in vitro* human stratum corneum] (Hostynek et al., 2001; Tanojo et al., 2001; EURA, 2008-2009) INHALATION = 100% (aerodynamic diameter below 5 µm = respirable fraction), negligible (aerodynamic diameters >5 µm = non-respirable fraction) [Animal studies and read across from nickel chloride rat *in vivo* intratracheal instillation studies] (Medinsky et al., 1987; Benson et al., 1995; Carvalho and Ziemer, 1982; English et al., 1981; Clary, 1975; EURA, 2008-2009)
Acute toxicity	ORAL: LD_{50}= 361.9 mg $NiSO_4 \cdot 6H_2O$/kg bw. Classified as Category 4. [OECD Guideline 425] (EPSL, 2009a; FDRL, 1983) DERMAL: No studies have been found on acute toxicity by the dermal route but dermal absorption is low so toxicity is not expected. INHALATION: LC_{50}= 2.48 mg $NiSO_4 \cdot 6H_2O$/L. Classified as Category 4 [OECD Guideline 403 study] (EPSL, 2009b)
Skin corrosion/irritation	Nickel sulphate is classified as Category 2 for skin irritaton with a 20% concentration limit. [Human patch testing] (Frosch and Kligman, 1976; Seidenari et al., 1996)
Serious eye damage/irritation	Nickel sulphate is not an eye irritant. [OECD Guideline 405 study] (SLI, 1999)
Respiratory or skin sensitisation	DERMAL: Nickel sulphate is a dermal sensitizer classified as Category 1. [Guinea Pig Maximization Test sudies] (Rohold et al., 1991; FDRL, 1986; Lammintausta et al., 1985; Nielsen et al., 1992) RESPIRATORY: Nickel sulphate is a respiratory sensitizer classified as Category 1. [Weight of evidence from human case reports] (Block and Yeung, 1982; Malo et al., 1982; Malo et al., 1985; McConnell et al., 1973; Novey et al., 1983)
Germ cell Mutagenicity	Nickel sulphate is mutagenic and is classified Category 2. [*In vivo* mutagenicity testing and *in vivo* testing weight of evidence] (Larramendy et al., 1981; Oller and Erexson, 2007)
Carcinogenicity	ORAL: Nickel sulphate is not carcinogenic by the oral route of exposure. [OECD Guideline 451 and EPA OPPTS 870.4200 study] (Heim et al., 2007) DERMAL: Not relevant since negligible amount of absorption by dermal exposure. INHALATION: Nickel sulphate in currently classified as Category 1A for inhalation exposure. [Human epidemiological studies and 2-year rat inhalation OECD Guideline 453] (Doll et al., 1990; Grimsrud et al., 2002; Antilla et al., 1998; Roberts et al., 1989; Andersen et al., 1996; Pang et al., 1996; NTP, 1996)
Reproductive toxicity	Nickel sulphate is a Category 1B reproductive toxicant. [OECD Guideline 416- 2 generation study] (SLI, 2000)
STOT-single exposure	Available data do not indicate potential for single target organ toxicity. (References are included in other endpoint summaries.)
STOT-repeated dose toxicity	ORAL: Lack of toxicity demonstrated in available studies. (References are included in other endpoint summaries.) DERMAL: Lack of toxicity from dermal exposure since dermal absorption is negligible. INHALATION: Classified as Category 1 for inhalation exposure due to lung effects. NOAEC = 0.027 mg Ni/m^3 [Data from 2-year rat inhalation OECD Guideline 453 study] (NTP, 1996)
Aspiration hazard	Not applicable.

12. ECOLOGICAL INFORMATION

Endpoints	Description of effects
Toxicity	**Ecotoxicity Reference Values (ERVs) for nickel substances:** • Acute = 120 µg Ni/L (pH 6), 68 µg Ni/L (pH 8) • Chronic = 2.4 µg Ni/L **Short-term toxicity to aquatic invertebrates:** • Invertebrates 48h LC_{50} (immobilization) (freshwater): Range from 0.013 mg Ni/L [*Ceriodaphnia dubia*] (Schubauer-Berigan *et al.*, 1993) to 4970 mg Ni/L [*Daphnia magna*] (Chapman *et al.*, 1980) (immobilization). • Invertebrates 48h LC_{50} mortality (marine): Range from 0.23 mg/L [*Haliotis refescens*] (Hunt *et al.*, 2002) to 415 mg/L (*Penaeus duorarum*] (Bentley *et al.*, 1975). **Short-term toxicity to fish:** • Fish 96 hour (freshwater): Range from 0.23 mg Ni/L [*Pimephales promelas*] (Hoang *et al.*, 2004) to 320 mg Ni/L [*Brachydanio rerio*] (Janssen Pharmaceutica, 1993) (mortality). • Fish 96h LC_{50} mortality values (marine): Range from 26.6 mg Ni/L [*Atherinops affinis*] (Hunt *et al.*, 2002) to 350 mg Ni/L [*Fundulus heteroclitus*] (Eisler and Hennekey, 1977). **Long-term toxicity to aquatic invertebrates:** • Invertebrates population growth rate (15 species) (freshwater): Range of 1.4 µg/L [*Lymnaea stagnalis*] (growth) to 1379 µg/L [*Brachionus calyciflorus*] (Stubblefield and Van Genderen, 2007). • Invertebrates (9 species) (marine): Range from 22.5 µg Ni/L [*Neanthes arenaceodentata* reproduction] (Parametrix 2007b) to 335 µg Ni/L [*Strongylocentrotus purpuratus* development] (Parametrix 2007c). **Long-term toxicity to fish:** • Fish (3 species) (freshwater): Range of 40 µg Ni/L [*Brachydanio rerio* for hatchability] to 1548 µg Ni/L [*Oncorhynchus mykiss* for growth] *(*Deleebeeck *et al.*, 2007). • Fish EC_{10} (2 species) (marine): Range from 3599 µg Ni/L [*Atherinops affinis* growth] (Hunt *et al.*, 2002) to 20760 µg Ni/L [*Cyprinodon variegatus* growth] (Golder Associates, 2007). **Toxicity to aquatic algae and cyanobacteria:** • Algae growth rate (9 values) (freshwater): Range of 12.3 µg Ni/L [*Scenedesmus accumulates*] (Deleebeeck *et al.*, 2006) to 51.8 µg Ni/L [*Coelastrum microporum*] (Deleebeeck *et al.*, 2006) (growth rate) • Algae growth (4 species) (marine): Range from 97 µg Ni/L [*Macrocystis pyrifera*] (Golder, 2007) to 17891 µg Ni/L [*Dunaliella tertiolectal]* (Parametrix 2007a). **Toxicity to aquatic plants other than algae:** • Higher aquatic plants growth inhibition (freshwater): Range of 8.2 µg Ni/L [*Lemna gibba*] (Klain & Knuteson, 2003) and 80 µg Ni/L [*Lemna minor*] (Antunes, 2007) **Toxicity to microorganisms:** • Inhibition of Oxygen Consumption EC_{50}: 33 mg/L [Test for by Activated Sludge-ISO 8192] (Cokgor et al.,2007) **Toxicity to other aquatic organisms:** • Amphibians (3 species) (freshwater): Range of 84.5 µg Ni/L to 13,147 µg Ni/L [*Xenopus laevis* malformation] (Hopfer *et al.*, 1991). **Sediment toxicity:** • Pending outcome of sediment testing program (conclusion i of EU Existing Substances Risk Assessment).

	Toxicity to soil macro-organisms: • Macroinvertebrates (acute): Range from 52 mg Ni/kg dw [*Lumbicis terrestris* mortality] (Furst *et al*., 1993) to 2,500 mg Ni/kg dw [*Caenorhabditis elegans* mortality] (Boyd and Williams, 2003). • Invertebrates (6 species) (chronic): Range from 36 mg Ni/kg [*Folsomia candidate* reproduction] to 1140 mg Ni/kg [*Eisenia fetida* reproduction] (Ghent University, 2005). **Toxicity to terrestrial plants:** • Plants EC_{50} (4 d) values (acute): Range from ≥54.5 mg/kg soil d.w. to ≤1928.2 mg/kg [*Hordeum vulgare* root elongation] (Thakali *et al*., 2006). • Plants (11 species) (chronic): Range from 10 mg Ni/kg [*Spinacea oleracea* total yield] (Willaert & Verloo, 1988) to 1127 mg Ni/kg [*Hordeum vulgare* root yield] (Rothamsted Research, 2005). **Toxicity to soil micro-organisms:** • Microbial processes (12 processes) (chronic): Range from 28 mg Ni/kg [nitrification] (Smolders, 2000) to 2542 mg Ni/kg [respiration] (Doelman & Haanstra, 1984). • Enzyme activity in soil (chronic): Range from 7.9 mg Ni/kg [dehydrogenase] (Welp, 1999) to 7084 mg Ni/kg [arylsulfatase activity] (Haanstra and Deolman, 1991). • Microbial species growth (13 species) (chronic): Range from 13 mg Ni/kg [*Aspergillus clavatus*] to 530 mg Ni/kg for [*Trichoderma viride*] (Babich & Stotzky, 1982).
Persistence and degradability	Not applicable to inorganic substances. Information about the extent of nickel partitioning from the water column and transformation to less toxic or non-toxic nickel species is currently being evaluated in the context of the CLP criteria. This evaluation will be completed and available by 1 December 2012.
Bioaccumulative potential	**<u>Aquatic bioaccumulation</u>** • Freshwater aqueous: Range from 0.8 [*Oncorhynchus mykiss*, muscle w.w., 180 d flow-through] (Calamari et al., 1982) to 5613 [*Anacystis nidulans*, whole body d.w., 48h static] (Azeez and Banerjee, 1991) • Freshwater sediment: 6150 [*Cerastoderma edule,* whole body w.w., field study] (Bryan and Hummerstone, 1977) • Saltwater aqueous: Range from 3 (*C. margaritacea*, whole body w.w., field study] (Walting, 1983) to 26500 (*Cerastoderma edule* whole body d.w., 26 d semi-static] (Waegeneers and Smolders, 2003) • McGeer et al. (2003) aggregated whole fish tissue data published by Lind et al. (1978) and Blaylock and Frank (1979). A BCF of 270 was calculated from this linear relationship. Where *C. edule* was a relevant prey item for marine food chains, the value of 1631 (Boyden, 1975) was relevant. **<u>Terrestrial bioaccumulation (BSAF)</u>** • Range from 0.013 [lettuce, edible fraction] (DiSalvatore et al., 2009) to 1.86 [*Allolobophora caligonosa*, whole body d.w. (Plaggen soil)] (Ma, 1982) • All BAFs were pooled and log normally distributed, resulting in a BAF geometric mean from the cumulative frequency distribution of 0.30 (EURA, 2008-2009)

Mobility in soil	**K_p- Soil:** log $K_{p\ soil}$ 2.86 [Aqua regia digestion- ISO 11466, 46 European soils](De Groot et al., 1998).
Results of PBT and vPvB assessment	The PBT and vPvB criteria of Annex XIII to the Regulation does not apply to inorganic substances, such as nickel and inorganic nickel compounds.
Other adverse effects	Not applicable.

13. DISPOSAL CONSIDERATIONS

Product:
A distinction must be made between "wastes for recycling" and "wastes for disposal". Please contact the competent body (authority or waste disposal company) where you will obtain information on recycling or disposal.

Packaging:
Disposal to be in compliance with official regulations. Handle contaminated packaging in the same way as the substance itself. If not officially specified differently, non-contaminated packaging may be treated like household or recycled.

14. TRANSPORT INFORMATION

Land transport - Transport according to SABS code of practice (0230, 0231,0232)

Sea Transport - Ship in a closed container.

UN Proper Shipping Name - ENVIRONMENTALLY HAZARDOUS SUBSTANCE SOLID N.O.S. (Nickel Sulphate)
Transport Hazard Class: 9
Packaging Group: III
The transport regulations are cited according to International Regulations, and may depend on Country-to-Country and volume to be transported.

15. REGULATORY INFORMATION

Labeling:
Hazard pictograms:

Signal word: danger

Hazard statements:

LABELLING Hazard Statement Code	HAZARDOUS STATEMENT CODE DESCRIPTION
H302	H302 = Harmful if swallowed
H315	H315 = Causes skin irritation
H317	H317 = May cause an allergic skin reaction
H332	H332 =Harmful if inhaled
H334	H334 = May cause allergy or asthma symptoms or breathing difficulties if inhaled
H341	H341 = Suspected of causing genetic defects
H350i	H350i = May cause cancer via inhalation
H360D	H360D = May damage the unborn child
H372	H372 =Causes damage to lungs through prolonged or repeated exposure via inhalation
H410	H400 = Very toxic to aquatic life
	H410 =Very toxic to aquatic life with long lasting effects

EC No - 232-104-9

16. OTHER INFORMATION

References: Toxicity Summary Nickel Sulphate
References: Ecotoxicity Summary Ni and Ni compounds
Refer to Annexure A of this MSDS – NOTE: Please don't print the list of references – save paper

DISCLAIMER

All information is given in good faith but without guarantee in respect of accuracy, and no responsibility is accepted for errors or omissions or the consequences thereof. It is the user's obligation to determine the conditions of safe use of the material, all risks of use of the product are therefore assumed by the user and we expressly disclaim all warranties of every kind and nature, including warranties of merchantability and fitness for a particular purpose in respect to the use or suitability of the product.

Annexure A: List of References

References: Toxicity Summary Nickel Sulphate

Andersen A, Engeland A, Berge SR, Norseth T. (1996). Exposure to nickel compounds and smoking in relation to incidence of lung and nasal cancer among nickel refinery workers. Occup Environ Med, 53:708-13.

Anttila A, Pukkala E, Aitio A, Rantanen T, Karjalainen S. (1998). Update of cancer incidence among workers at a copper/nickel smelter and nickel. Int Arch Occup Environ Health, 71:245-50.

Benson JM, Chang IY, Cheng YS, Hahn FF, Kennedy CH, Barr EB, Maples KR, Snipes MB (1995). Particle clearance and histopathology in lungs of F344/N rats and B6C3F1 mice inhaling nickel oxide or nickel sulfate. Fundam Appl Toxicol, **28:**232-244.

Block, G. T. and M. Yeung (1982). Asthma induced by nickel. JAMA, 247(11):1600-2.
Carvalho SMM and Ziemer PL. (1982). Distribution and clearance of ^{63}Ni administered as ^{63}NiCl2 in the rat: Intratracheal study. Arch Environ Contam Toxicol, 11:245-248.

Clary JJ. (1975). Nickel chloride-induced metabolic changes in the rat and guinea pig. Toxicol Appl Pharmacol.; 31:55-65.

Diamond GL, Goodrum PE, Felter SP and Ruoff WL. (1998). Gastrointestinal absorption of metals. Drug Chem Toxicol, 21:223-251.

Doll et al. (International Committee on Nickel Carcinogenesis in Man (ICNCM)). (1990). Report of the International Committee on Nickel Carcinogenesis in Man. Scand J Work Environ Health, 16:1-84.

EPSL (2009a). Acute Oral Toxicity Up and Down Procedure in Rats. Testing laboratory: Eurofins Product Safety Laboratories (EPSL); Dayton, New Jersey, USA. Owner company: Nickel REACH Consortia Members. Study number: 28434. Report date: 2009-12-01.

EPSL (2009b). Acute Inhalation Toxicity Study in Rats - Defined LC50. Testing laboratory: Eurofins Product Safety Laboratories (EPSL); Dayton, New Jersey, USA. Owner company: Nickel REACH Consortia Members. Study number: 27562. Report date: 2009-09-29.

EURA (2008-2009). European Union Risk Assessment Report for Nickel Sulphate. Danish Environmental Protection Agency. Risk Assessment for Nickel Sulphate (CAS No. 7786-81-4)(EINECS No. 232-104-9) Prepared in Relation to Council Regulation (EEC) 793-93. http://www.mst.dk/English/Chemicals/Substances_and_materials/Nickel/
English JC, Parker RD, Sharma RP and Oberg SG. (1981). Toxicokinetics of nickel in rats after intratracheal administration of a soluble and insoluble form. Am Ind Hyg Assoc J, 42:486-492.

FDRL (Food & Drug Research Laboratories, Inc.) (1983). Acute Oral LD50 Study in Rats (OECD). Test Article 83-0506 (Nickel Sulfate). Testing laboratory: Food & Drug Research Laboratories, Inc. (FDRL). Report no.: FDRL Study No. 7702A. Owner company: Study conducted for NiPERA, Inc.

FDRL (Food & Drug Research Laboratories, Inc.) (1986). Dermal Contact Sensitization Study of Nickel Sulfate, Nickel Oxide, CT-243-850, and CT-243-85F. Guinea Pig Maximization Test. Testing laboratory: Food & Drug Research Laboratories, Inc. (FDRL). Report no.: 8932. Owner company: NiPERA, Inc. Report date: 1986-04-07.

Frosch PJ, Kligman AM (1976): The chamber scarification test for irritancy. Contact Dermatitis, 2:314-324.

Grimsrud TK, Berge SR, Haldorsen T, Andersen A. (2002). Exposure to different forms of nickel and risk of lung cancer. Am J Epidemiol, 156:1123-1132.

Heim KE, Bates HK, Rush RE, and Oller AR (2007). Oral carcinogenicity study with nickel sulfate hexahydrate in Fischer 344 rats. Toxicology and Applied Pharmacology. 224:126–137.
Hostynek, J.J.; Dreher, F.; Nakada, T.; Schwindt, D.; Anigbogu, A.; Maibach, H.I. (2001) Human Stratum Corneum Adsorption of Nickel Salts: Investigation of Depth Profiles by Tape Stripping in vivo. Acta Derm Venereol **S212**: 11-18.
Ishimatsu S, Kawamoto T, Matsuno K, Kodama Y. (1995). Distribution of various nickel compounds in rat organs after oral administration. Biol Trace Elements Res, 49 (1):43–52.

Lammintausta K, Kalimo K, and Jansen CT. (1985). Experimental nickel sensitization in the guinea pig: comparison of different protocols. Contact Dermatitis, 12:258-262.

Larramendy ML, Popescu NC, and DiPaolo JA (1981). Induction by inorganic metal salts of sister chromatid exchange and aberrations in human and Syrian hamster cell strains. Environmental Mutagenesis, 2:597-606.

Malo JL, Cartier A, Doepner M, Nieboer E, Evans S, and Dolovich J. (1982). Occupational asthmatic caused by nickel sulfate. J Allergy Clin Immunology, 69:55-59.

Malo JL, Cartier A, Gagnon G, Evans S, and Dolovich J. (1985). Isolated late asthmatic reaction due to nickel sulphate without antibodies to nickel. Clinical Allergy, 15:95-99.

McConnell LH, Fink JN, Schlueter DP and Schmidt MG, Jr. (1973). Asthma caused by nickel sensitivity. Ann Intern Med, 78(6):888-90.

Medinsky MA, Benson JKM, Hobbs CH (1987). Lung clearance and disposition of ^{63}Ni in F344/N rats after intratracheal instillation of nickel sulphate solutions. Environ Res, **43:**168-178.

NTP (National Toxicology Program). (1996a). Technical Report on the toxicology and carcinogenesis studies of nickel sulfate hexahydrate (CAS NO. 10101-97-0) in F344/N rats and B6C3F1 mice (inhalation studies). National Institute of Health, Springfield, VA. Washington DC. pp. 376. Testing laboratory: NTP (National Toxicology Program). NTP Technical Report No. 454. Owner company: National Institute of Health, Springfield, VA. Washington DC. Study number: NIH Publication No. 96-3370.

Nielsen, G. D., A. E. Rohold, and K. E. Andersen. (1992). Nickel contact sensitivity in the guinea pig. Acta Derm. Venereol. 72(1):45-48.

Nielsen GD, Søderberg U, Jørgensen PJ, Templeton DM, Rasmussen SN, Andersen KE, Grandjean P (1999). Absorption and retention of nickel from drinking water in relation to food intake and nickel sensitivity. Toxicol Appl Pharmacol, 154:67-75.

Novey, H. S., M. Habib and I. D. Wells (1983). "Asthma and IgE antibodies induced by chromium and nickel salts." J Allergy Clin Immunol, 72(4):407-12.

Oller A and Erexson G (2007). Lack of micronuclei formation in bone marrow of rats after repeated oral exposure to nickel sulfate hexahydrate. Mutation research, 626(1-2):102-110.

Pang D, Burges DC, Sorahan T. (1996). Mortality study of nickel platers with special reference to cancers of the stomach and lung, 1945-93. Occup Environ Med 53, 714-7.

Rohold AE, Nielsen GD, and Andersen KE (1991). Nickel sulphate-induced contact dermatitis in the guinea pig maximization test: A dose-response study. Contact Dermatitis, 24(1):35-39.

SLI (1999). A Primary Eye Irritation Study in Rabbits with Nickel Sulphate Hexahydrate. Testing laboratory: Springborn Laboratories, Inc. Report no.: SLI Study No. 3472.2. Owner company: Study conducted for NiPERA, Inc. Report date: 1999-12-23.

SLI (2000). An oral (gavage) two-generation reproduction toxicity study in Sprague-Dawley rats with nickel sulfate hexahydrate. Testing laboratory: Springborn Laboratories, Inc. Spencerville, Ohio, USA. Report no.: SLI Study No.

Seidenari, S., Belletti, B., Mantovani, L., and Pepe, P. (1996). Nickel sulfate 5-20% aq. Does not evoke irritation on the skin of non-nickel-sensitive subjects. Contact Dermatitis, 35:260-261.

Sorahan T. (2004). Mortality of Workers at a Plant Manufacturing Nickel Alloys, 1958-2000. Occupational Medicine, 54:28-34.

Sunderman FW, Jr, Hopfer SM, Sweeny KR, Marcus AH, Most BM, Creason J (1989). Nickel absorption and kinetics in human volunteers. Proc Soc Exp Biol Med, 191:5-11.

Tanojo H, Hostynek JJ, Mountford HS, and Maibach HI. (2001). *In vitro* permeation of nickel salts through human stratum corneum. Acta Derm Venereol, Suppl 212:19-23.

References: Ecotoxicity Summary Ni and Ni compounds

Antunes P. (Stantec Consulting Ltd) (2007). Testing the toxicity of Ni to Lemna minor in natural waters and standard test media. Testing laboratory: Stantec Consulting Ltd., Guelph, Ontario. Report no.: 162704389. Owner company: Nickel Producers Environmental Research Association (NiPERA), Inc.
Azeez PA and Banerjee DK. (1991). Nickel uptake and toxicity in cyanobacteria. Toxicological and Environmental Chemistry; 30:43-50.
Babich H and Stotzky G. (1982). Toxicity of nickel to microorganisms in soil: influence of some physiochemical characteristics. Environmental Pollution; (Series A) 29:303-315.
Bentley RE, Heitmuller T, Sleight III BH, and Parrish PR. (1975). Acute toxicity of nickel to bluegill (Lepomis macrochirus), rainbow trout (Salmo gairdneri), and pink shrimp (Penaeus duorarum). U. S. EPA, Criteria Branch (WH-585). Washington, D. C. Order No. WA-6-99-1414-B. Owner company: US EPA.
Blaylock BG and Frank ML. (1979). A comparison of the toxicity of nickel to the developing eggs and larvae of carp (Cyprinus carpio). Bull. Environ. Contam. Toxicol.; 21(4/5):604-611.
Boyd WA and Williams PJ (2003). Availability of metals to the nematode Caenophabditis elegans: Toxicity based on total concentrations in soil and extracted fractions. Env Toxicol and Chem, 22(5):1100-1106.
Boyden CR (1975). Distribution of some trace metals in Poole Harbor, Dorset. Marine Pollution Bulletin, 6(12):180-187.
Bryan GW and Hummerstone LG (1977). Indicators of heavy metal contamination in the looe estuary (cornwall) with particular regard to silver and lead. J Mar Bio Ass UK, 57:75-92.
Calamari D, Gaggino GF, and Pacchetti G (1982). Toxicokinetics of low levels of Cd, Cr, Ni and their mixture in long-term treatment of Oncorhynchus mykiss. Chemosphere, 11(1):59-70.
Chapman GA, Ota S, and Recht F (1980). Effects of water hardness on the toxicity of metals to Daphnia magna. US EPA, Corvallis, OR. 17p. Owner company: US EPA.
Cokgor EU, Ozdemir S, Karahan O, Insel G, and Orhon D. (2007). Critical appraisal of respirometric methods for metal inhibition on activated sludge. Journal of Hazardous Materials, B139:332–339.
De Groot AC, Peijnenburg WJGM, van den Hoop MAGT, Ritsema R, and van Veen RPM. (1998). Heavy metals in Dutch field soils: an experimental and theoretical study on equilibrium partitioning. Testing laboratory: Laboratory of Ecotoxicology, National Institute of Public Health and the Environment. Report no.: 607220001. Owner company: Laboratory of Ecotoxicology, National Institute of Public Health and the Environment.
Deleebeeck NME, De Schamphelaere KAC, Muyssen BTA, De Laender F, and Janssen CR. (Ghent University) (2006). Ni toxicity to soft vs. hard water organisms: a comparison of sensitivity and bioavailability. Testing laboratory: Ghent University (UGent). Laboratory of Environmental Toxicology and Aquatic Ecology. Owner company: Nickel Producers Environmental Research Association (NiPERA), Inc.
Deleebeeck NME, Muyssen BTA, De Laender F, Janssen CR, and De Schamphelaere KAC. (2007). Comparison of nickel toxicity to Cladocerans in soft versus hard surface waters. Aquatic Toxicology; 84:223-235. Testing laboratory: Laboratory of Environmental Toxicology and Aquatic Ecology, Gent University, Jozef Plateaustraat 22, Gent, Belgium.
DiSalvatore M, Carratu G, and Carafa AM. (2009). Assessment of heavy metals transfer from a moderately polluted soil into the edible parts of vegetables. Journal of Food, Agriculture, and Environment; 7(2):683-688.
Doelman P and Haanstra L. (1984). Short-term and long-term effects of cadmium, chromium, copper, nickel, lead and zinc on soil microbial respiration in relation to abiotic soil factors. Plant and Soil. 79:317-327.
ECHA (European Chemicals Agency) (2011). Guidance on the Application of the CLP Criteria. ECHA Reference: ECHA-11-G-06-EN. Date: 04/2011.
EURA (European Union Risk Assessment) (2008-2009). Danish Environmental Protection Agency. Background document in support of individual risk assessment reports of nickel compounds. Danish Environmental Protection Agency. Prepared in Relation to Council Regulation (EEC) 793-93. http://www.mst.dk/English/Chemicals/Substances_and_materials/Nickel/
Eisler R and Hennekey RJ. (1977). Acute toxicities of Cd^{+2}, Cr^{+6}, Hg^{2+}, Ni^{2+} and Zn^{2+} to estuarine macrofauna. Arch. Environ. Contam Toxicol, 6:315-323.
Ghent University/Euras (2005). NiPERA Research Project - Bioavailability and ageing of nickel in soils: Invertebrate toxicity testing. Testing laboratory: Ghent University (UGent) - Laboratory of Environmental Toxicology and Aquatic Ecology. Owner company: Nickel Producers Environmental Research Association (NiPERA), Inc. Report date: 2005-04-26.
Golder Associates Ltd. (2007). Laboratory report on: Toxicity of nickel to giant kelp (Macrocysts pyrifera) and sheepshead minnow (Cyprinodon vareigatas). Testing laboratory: Golder Associated Ltd. Report no.: 06-1424-008. Owner company: Nickel Producers Environmental Research Association (NiPERA), Inc. Report date: 2007-02-15.
Haanstra L and Doelman P (1991). An ecological dose-response model approach to short- and long-term effects of heavy metals on arylsulphatase activity in soil. Biology and Fertility of Soils, 11:18-23.
Hoang, TC, Tomasso JR, and Klaine SJ. (2004). Influence of water quality and age on nickel toxicity to fathead minnows (Pimephales promelas). Environ. Toxicol. Chem.; 23(1):86-92.
Hopfer SM, Plowman MC, Sweeney KR, Bantle JA, and Sunderman Jr. FW. (1991). Teratogenicity of Ni+2 in Xenopus laevis, assayed by the FETAX procedure. Biological Trace Element Research, 29:203-216.

Hunt JW, Anderson BS, Phillips BM, Tjeerdema RS, Puckett HM, Stephenson M, Tucker DW, and Watson D. (2002). Acute and chronic toxicity of nickel to marine organisms: Implications for water quality criteria. Environmental Toxicology and Chemistry; 21(11):2423 - 2430.
Janssen Pharmaceutica (1993). The acute toxicity of nickel chloride in the zebra fish (Brachydanio rerio). Testing laboratory: Study conducted by Janssen Pharmaceutica N. V., Beerse, Belgium. Report no.: AFBr/0015. Owner company: Nickel Producers Environmental Research Association (NiPERA), Inc. Report date: 1993-01-19.
Klaine SJ and Knuteson S. (Clemson Institute of Environmental Toxicology, Clemson University) (2003). Toxicity of nickel to duckweeds. Clemson Institute of Environmental Toxicology, Clemson University, Pendleton, South Carolina. Testing laboratory: Clemson Institute of Environmental Toxicology, Clemson University. Owner company: Nickel Producers Environmental Research Association (NiPERA), Inc. Report date: 2003-12-31.
Lind D, Alto K, and Chatterton S. (1978b). Regional Copper-Nickel Study: Aquatic toxicology study. Minnesota Environmental Quality Board. pp. 1-53.
Ma W (1982). The influence of soil properties and worm-related factors on the concentration of heavy metals in earthworms. Pedobiologia, 24:109-119.
McGeer JC, Brix KV, Skeaff JM, DeForest DK, Brigham SI, Adams WJ, and Green AS. (2003). The inverse relationship between bioconcentration factor and exposure concentration for metals: implications for hazard assessment of metals in the aquatic environment. Environ. Toxicol. Chem.; 22(5):1017-1037.
Parametrix, Inc. (2007a). Toxicity of nickel in natural waters to the marine algae (Dunaliella tertiolecta). Testing laboratory: Parametrix Environmental Research Laboratory, 33972 Texas Street SW, Albany, OR 97321. Report no.: 3831-425. Owner company: Nickel Producers Environmental Research Association (NiPERA), Inc. Report date: 2007-05-14.
Parametrix, Inc. (2007b). Toxicity of nickel to Neanthes arenaceodentata. Testing laboratory: Parametrix Environmental Research Laboratory, 33972 Texas Street SW, Albany, OR 97321. Report no.: 3831-457. Owner company: Nickel Producers Environmental Research Association (NiPERA), Inc. Report date: 2007-05-16.
Parametrix, Inc. (2007c). Toxicity of nickel to the sand dollar, Dendraster excentricus, and the purple sea urchin, Strongylocentrotus purpuratus. Testing laboratory: Northwestern Aquatic Sciences, 3814 Yaquina Bay Rd., Newport, OR 97365. Report no.: 760-8. Owner company: Nickel Producers Environmental Research Association (NiPERA), Inc. Report date: 2007-03-07.
Rothamsted Research (2005). NiPERA Research Project - Development of a predictive model of bioavailability and toxicity of nickel in soils: Plant toxicity. Testing laboratory: Rothamsted Research. Owner company: Nickel Producers Environmental Research Association (NiPERA), Inc. Report date: 2005-01-01.
Schubauer-Berigan MK, Dierkes JR, Monson PD, and Ankley GT. (1993). pH-Dependent toxicity of Cd, Cu, Ni, Pb and Zn to Ceriodaphnia dubia, Pimephales Promelas, Hyalella azteca and Lumbriculus variegates. Environmental Toxicology and Chemistry, 12:1261-1266.
Smolders E. (2000). The effect of $NiSO_4$.6H2O, elemental Ni and green NiO on nitrogen transformation in soil. Final Report. Reported in conjunction with the Nickel Producers Environmental Research Association (NiPERA), Inc. 22p. Testing laboratory: University of Leuven. Report date: 2000-01-01.
Stubblefield W and Van Genderen E (Parametrix, Inc) (2007). Validation of nickel biotic ligand model predictions for selected non-standard organisms. Testing laboratory: Parametrix, Inc. Owner company: Nickel Producers Environmental Research Association (NiPERA), Inc.
Thakali S, Allen HE, Di Toro DM, Ponizovsky AA, Rooney GP, Zhao FJ, and McGrath SP (2006). A terrestrial biotic ligand model. 1. development and application to cu and ni toxicities to barley root elongation in soils. Environ Sci Technol, 40:7085-7093.
Waegeneers N and Smolders E. (2003). Secondary poisoning of nickel to marine birds. EU Risk Assessment. Testing laboratory: Laboratory for soil and water management, KasteelPark Arenberg 20, B-3001 Heverlee-Belgium. Owner company: NiPERA, Inc.
Walting HR (1983). Accumulation of seven metals by Crassostrea gigas, Crassostrea margaritacea, Perna perna, and Choromytilus meridionalis. Bull. Environ Contam Toxicol, 30:317-322.
Welp G. (1999). Inhibitory effects of the total and water-soluble concentrations of nine different metals on the dehydrogenase activity of a loess soil. Biology and Fertility of Soils; 30:132-139.
Willaert G and Verloo M. (1988). Biological effects of nickel species and their determination in plant and soil. Plant and Soil; 107:285-292.