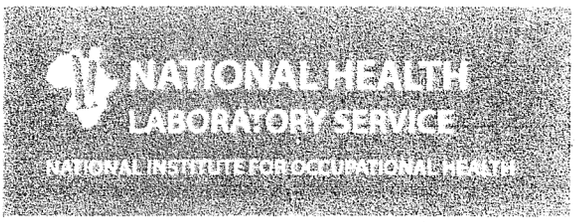

Preliminary Report on the Survey of Namibia Customs Smelter Workers Tsumeb, Namibia

August 2013

Occupational Medicine,
National Institute for Occupational Health (NIOH)

Supported by the Ministry of Environment and Tourism of Namibia

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Introduction

This is a preliminary report on the survey conducted at Namibia Customs Smelters (NCS) between March 2013 and July 2013. A detailed report will follow which will include information on the outcome of specialist referrals and assessment of occupational diseases.

Background

The Namibia Customs Smelter (NCS) is a major commercial smelter, located in Tsumeb, Republic of Namibia. The smelter has been operational since the 1960's and primarily serves to process copper. It is unique in that it is one of the few smelters with the ability to treat complex arsenic and lead-bearing copper concentrates. The final products produced from the process include blister copper bars, which are then delivered to refineries, and arsenic trioxide which is sold to manufacturers of pesticides and wood treatment products.[1]

In 2012, NCS smelted 159,356 tonnes of copper concentrate. Recent refurbishments to the plant aim to increase the smelter capacity from 170,000 - 200,000 tonnes per year to 240,000 tonnes per year. (Annual report 2012).

The health and safety aspects of NCS's operations have become an area of concern for the government of Namibia, the owners of NCS, the workers at the smelter and the local community of Tsumeb. Air concentrations of arsenic above generally accepted occupational exposure limits have been recorded at the smelter for decades; for example with violations of the exposure standard of 0.2 mg/m^3 documented from 1985 to 1990 [Smelter Environmental Report For Spring (Sept 1990 to Nov 1990)].

The Ministry of Environment and Tourism (MET), Republic of Namibia, approached the National Institute for Occupational Health of South Africa (NIOH) to partner with the MET in conducting several studies including a medical survey of the NCS workers.

Health effects of Arsenic

The workplace hazards considered in the survey of Namibia Custom Smelters (NCS) workers were inorganic arsenic, sulphur dioxide, heat and noise with inorganic arsenic being the most prominent and toxic.

Acute, sub-acute and chronic exposure to inorganic arsenic (arsenic from now on) has been associated with a variety of health effects. Table 13 lists the more important of these health effects, excluding cancers. Acute, sub-acute and chronic symptoms and signs may be pertinent in NCS workers given the high levels of arsenic exposure recorded over many years and also recently.

[1]Dundee Precious Metals. Process overview of Tsumeb Smelter.[Internet]. 2012 [cited 2013 Aug 20]. Available from: http://www.dundeeprecious.com/English/operations/processing/tsumeb-smelter/overview/default.aspx

Having stated this, it is noteworthy that the acute effects of arsenic exposure are rare following industrial exposure. In these employees, respiratory symptoms, giddiness, headaches and weakness are usually the first to present followed by Gastro-intestinal symptoms.[2]

It is still unclear whether some of these health effects are limited to ingestion of arsenic as opposed to inhalation. Some of the symptoms and signs listed in Table 13 are less well established than others. Almost all of the health effects are non-specific, having many causes besides arsenic, including other hazards typically present in copper smelters, for example sulphur dioxide. Additionally, exposed workers may have sub-clinical effects (for example, slowed peripheral nerve conduction, inhibition of Clara cell protein secretion and increased urinary β2-microglobulin) which would not be apparent to the worker (asymptomatic) or to a doctor doing a physical examination. Some are clinically apparent (for example skin rashes and gastro-intestinal (GIT) symptoms); and some would manifest only after prolonged exposure or a long latent period from first exposure or both e.g. cancers.

The most visible clinical findings noted are skin changes which are often due to arsenic's irritant properties and may cause a contact dermatitis in moist, macerated areas like the eyelids, angles of ears, nose and mouth and respiratory mucosa. Changes to the respiratory mucosa in the nose may eventually cause nasal perforations. In addition to the irritant effect of arsenic, it is also a skin sensitizer and in chronic exposure produces thickening of the skin (keratosis) of the palms and soles and also pigmentation changes to the skin as well as hair loss.[3]

The historical significance of exposure to high levels of arsenic at NCS necessitates the need for a thorough investigation for evidence of chronic effects of arsenic in NCS workers. Other than the skin changes already mentioned, chronic hepatitis, cirrhosis of the liver and peripheral neuropathies may also be a feature of this. Mees lines which are horizontal white lines on the finger and toe nails are considered diagnostic in combination with polyneuritis in chronic arsenic exposure.[3]

Inorganic arsenic is a recognised human carcinogen. The International Agency for Research on Cancer (IARC) concluded its 2011 Monograph by stating: "There is sufficient evidence in humans for the carcinogenicity of mixed exposure to inorganic arsenic compounds, including arsenic trioxide, arsenite, and arsenate. Inorganic arsenic compounds, including arsenic trioxide, arsenite, and arsenate, cause cancer of the lung, urinary bladder and skin. Also, a positive association has been observed between exposure to arsenic and inorganic arsenic compounds and cancer of the kidney, liver, and prostate." Besides skin lesions, one would not expect to identify these cancers during a cross-sectional assessment of workers given the lag time in developing cancers and the possibility of the 'healthy worker effect".

Arsenic exposure at NCS

Air concentrations of arsenic above generally accepted occupational exposure limits have been recorded at the smelter for decades, with violations of the exposure standard of 0.2 mg/m^3 documented from 1985 to 1990 [Smelter Environmental Report For Spring (Sept 90 to Nov 1990);

[2] Occupational health and Safety Administration. Arsenic medical surveillance guidelines- 1910.1018 App C. [Internet].2005 [cited 2013 Aug 20]. Available from: https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10026

Tsumeb Smelter Industrial Hygiene and Environmental Affairs]. Recent urinary arsenic concentrations confirm current widespread over-exposure at the plant. For example, the NCS Health Quarterly Review Quarter 1 of Summer 2011 shows an average urinary arsenic concentration of 232 µg/g creatinine in the Copper Plant in January 2011 and 389 µg/g creatinine in the Arsenic Plant in the same month. The NCS Health Quarterly Review Quarter 2 in Autumn shows the average to have been 251 µg/g creatinine in the Copper Plant and the Arsenic Plant in March 2011. The 2011 Biological Exposure Index (BEI) – the reference value above which over-exposure is assumed – of the American Conference of Governmental Industrial Hygienists (ACGIH) for elemental and soluble inorganic compounds is 35 µg/litre and the South African BEI, also for inorganic arsenic and metabolites, is 50 µg/g creatinine [Regulations for Hazardous Chemical Substances, 1995, Department of Labour]. It should be noted that some laboratories use 100 µg/g creatinine as the reference value for over-exposure and that a variety of international agencies have action levels (i.e. levels which trigger intervention) at about 150 ug/g creatinine.

Furthermore a preliminary study at NCS showed high concentrations of urinary arsenic during biological monitoring and emphasized the need for further investigation of chronic health effects due to occupational exposure to arsenic.

Objective of the preliminary report

The preliminary report on the occupational health survey of employees and ex-employees at NCS included the results of:

- the clinical assessment;
- the bio-clinical and other diagnostic assessments;
- the referral of certain employees and ex-employees for further assessments;
- possible work related exposures and associated clinical and bio-clinical effects.

Methods and materials

The survey was conducted using a cross sectional design between March 2013 and July 2013, and was a comprehensive medical assessment of all NCS employees and ex-employees. Both exposure and outcome data were collected at the same time of the survey and analysed accordingly.

Study Population

The study population was NCS employees and ex-employees who had worked in the company between June 2010 and October 2012 as permanent employees or contractor employees.

Data collection, management and analysis

A data collection tool was designed and used for the medical assessment exercise. Data collected was on demographic details, occupational and exposure history, medical history and general health status. The symptoms related to the main occupational exposures (arsenic, sulphur dioxide and lead) and the results of investigations conducted and physical examination were also collated and analysed. The data collection tool contained a nurse administered questionnaire, test results and details of the physical examinations conducted by an occupational medical practitioner. Nine professional nurses were trained on questionnaire administration and clinical documentation for completion of forms. The questionnaire although in English was administered in the patients'

preferred language by the nurse interviewers. Five occupational medical practitioners (three Namibian and two South African) were trained on clinical guidelines to be used for the study as part of standardisation of clinical assessment and reporting. Based on the assessment of the occupational medical practitioner, employees suspected of having an occupational disease were referred to a specialist or a local occupational medicine practitioner (Dr Badenhorst). In employees where non occupational disease was found but further investigation and management of the condition was indicated, employees were referred to their general practitioner or the local government health facility.

Results of urine and blood analysis collected a few months prior to the commencement of the study, were used as indicators of arsenic and lead exposure. These had been collected as part of the routine medical surveillance and biological monitoring programme in the company. No speciation had been conducted for urinary arsenic levels although they were corrected for creatinine.

A master file containing a list of employees to be assessed during the survey was prepared by the NCS human resources division and detailed the work stations, the employee's unique number and numbers of employees scheduled to be examined each day. Basic identification data was collected from each employee for registration and verification with information provided by the company list. This information was then used to compile an attendance register and planning and scheduling for attendance on a daily basis.

The following data was collected on each participant, in line with their occupational exposure:

a) Demographic details
b) Occupational status, history and exposure in various departments (work stations)
c) Medical history
d) Symptoms
e) Urine dipstix
f) Height, Weight and Body Mass Index
g) Audiometric test
h) Lung function test
i) Snellen's vision test
j) Urine arsenic level
k) Blood lead levels
l) Full blood count
m) Serum- Alanine aminotransferase (ALT)
n) Full liver function test, where clinically indicated.

On site diagnostic services such as audiometry and spirometry was done by OCNAM. Tsumeb private hospital provide the radiology services and the clinical facilities. Data capture was contracted out to Occupational Care South Africa (OCSA). Data was entered from original source documents using OCSA's software program from which a database was collated. Data was analysed by a biostatistician at NIOH using Stata version 12.

Results

NCS demographics

Table 1: NCS employee employment status by type

	Employee (%)	Ex-Employee (%)	Total
Contractor	933 (73%)	340 (27%)	1273
Permanent	458 (94%)	28 (6%)	486
Total	1391 (79%)	368 (21%)	1759

Table 2: Age distribution of NCS employees

Age group	Number	Percent
18-20	18	1
21-30	576	33
31-40	539	31
41-50	311	18
51-60	236	14
61+	42	2
Total	1 722	100

Table 3: Gender distribution

	Number	Percent
Male	1667	94.8 %
Female	92	5.2 %

1 759 surveyed employees were assessed during the survey; comprising 458 current NCS employees, 933 contract workers on site at the time of the survey and 368 former employees. More detailed analyses will be presented in the final report including diagnoses of occupational disease by nature of disease and an examination of the associations between arsenic exposure and parameters such as Alanine aminotransferase (ALT) and Haemoglobin (Hb).

Table 4 shows the number of employees evaluated by current section or last section for former workers, as reported by the employees.

Table 4: Number of employees evaluated by Section

Section	Employees	Ex-employees	Totals
Administration	135	10	145
Arsenic Plant	41	22	63
Copper Smelter	142	50	192
Engineering	180	37	217
Lab & Technical	25	2	27
Material Handling	67	6	73
Other	505	179	684
Service Provider	131	25	156
Slagmill	39	0	39
TLS Furnace	126	37	163
Total	1 391 (79%)	368 (21%)	1 759

Urinary Arsenic Concentrations by work sections and exposure ranking

Urinary arsenic concentrations are a measure of recent arsenic exposure. Unless speciated, urinary arsenic concentrations combine less toxic forms of arsenic (organic compounds, usually from the diet) and inorganic arsenic plus methylated metabolites (the latter two are generally considered a reflection of more toxic arsenic absorption). The urinary arsenic concentrations presented in Tables 5 and 6 are not speciated and thus combine all forms of arsenic (i.e. "total" arsenic). It is important to note that workplace arsenic reference values – e.g. biological exposure indices (BEI) – are for inorganic arsenic plus methylated metabolites (i.e. excluding organic compounds). Consequently, not all of the concentrations above 50 µg/g creatinine in Tables 2 and 3 should be taken to be above the South African workplace standard (BEI) of 50 µg/g creatinine. A common reference value for "total" arsenic in urine is 100 µg/g creatinine. Values above this concentration generally indicate excessive absorption of inorganic arsenic (but may be explained by organic arsenic consequent on a recent meal or meals rich in organic arsenic). Concentrations above 300 µg/g creatinine almost always reflect excessive absorption of inorganic arsenic from the workplace or environment.

One thousand and eighty two arsenic concentrations in current employees are presented in Table 5 by concentration category (lowest to highest category). About 69% of concentrations exceeded 100 µg/g creatinine.

Table 5: Urinary arsenic concentrations (µg/g creatinine) by category in current employees

Arsenic categories	Range of arsenic concentrations	Number	%	Median arsenic concentration
0-50	3-50	125	11.6	34
51-100	51-99	212	19.6	76
101-200	101-200	421	38.9	143

201-300	201-300	173	16	243
301-500	301-497	113	10.4	363
>500	507- 1357	38	3.5	657
		1 082	100	

Table 6 shows urinary arsenic concentrations by section. It is notable that concentrations > 300 µg/g creatinines were measured in all sections except the Slagmill.

Table 6: Urinary arsenic (µg/g creatinine) categories by Section for current employees

Section	0-50	51-100	101-200	201-300	301-500	>500	Total
Administration	51	25	30	0	1	1	108
Arsenic Plant	0	0	6	9	14	4	33
Copper Smelter	2	19	59	28	12	3	123
Engineering	28	36	54	15	14	2	149
Lab & Technical	2	6	6	0	3	0	17
Materials Handling	3	13	29	6	1	0	52
Other	25	76	142	85	44	17	389
Service Provider	6	18	26	13	14	4	81
Slagmill	1	10	21	4	0	0	36
TLS Furnace	7	9	48	13	10	7	94
Total	125	212	421	173	113	38	1 082

Symptoms and clinical features of the surveyed employees

Table 7 presents findings of the physical examination and laboratory tests from the evaluation of employees (current and ex-employees). Abnormal findings should not be regarded as being due to work; many are non-specific with many causes and some of the employees may have had exposures too short to result in a work related linkage. Further analysis is required to evaluate abnormal findings and these will be presented in the final report.

Table 7: Clinical and biochemical findings of employees

	CURRENT EMPLOYEES		EX-EMPLOYEES	
SIGNS	Number	%	Number	%
Pallor	3	0.2	5	1.4
Nasal perforation	4	0.3	0	0.0
Cataract	11	0.9	3	0.8
Chest wheeze	10	0.8	1	0.3
CVS Arrhythmia	11	0.8	1	0.3
SKIN				
Skin hyper pigmentation	69	5.5	21	5.8
Skin hypo pigmentation	26	2.1	12	3.3
Hyperkeratosis	33	2.6	7	2.0
Rash	194	15.4	45	12.4
Mees lines	9	0.7	3	0.8

Peripheral pulses absent	26	2.1	3	1.9
Ulcers on leg	4	0.3	3	0.8
Cold cyanotic extremities	2	0.2	2	0.6
LIVER AND NEUROLOGICAL				
Liver tenderness	5	0.4	4	1.1
Hepatomegaly	9	0.7	2	0.6
Positive neurologic findings	7	0.6	3	0.9
BODY MASS INDEX (BMI)				
Category	**Number**	**%**	**Number**	**%**
Underweight (<18.5)	79	6.0	44	7.3
Normal range (18.5 -<25)	697	54.5	253	58.0
Overweight (25-30)	344	26.9	52	14.4
Obese (>=30)	161	12.6	12	3.3
Total	1 278	100	361	100
BLOOD PRESSURE				
Category	**Number**	**%**	**Number**	**%**
Optimal	318	22.9	76	20.7
Normal	409	29.4	119	32.3
High normal	256	18.4	76	20.7
Grade 1 hypertension	224	16.1	71	19.3
Grade 2 hypertension	46	3.3	14	3.8
Grade 3 hypertension	138	9.9	12	3.3
Total	1 391	100	368	100
BLOOD LEAD (µG/DL)				
Category	**Number**	**%**	**Number**	**%**
<40	933	99.9	27	99.9
40- 59	0	0.0	0	0.0
>60	1	0.1	0	0.1
Total	934	100	27	100
HAEMOGLOBIN (G/DL)				
Category	**Number**	**%**	**Number**	**%**
<10	3	0.3	1	0.3
10-12	10	1.0	6	1.7
>12	1006	98.7	340	98.0
Total	1 019	100	347	100
SERUM ALANINE AMINOTRANSFERASE (ALT) IU/L				
Category	**Number**	**%**	**Number**	**%**
<=40	785	78.5	276	78.9
41-60	133	13.3	35	10.1
61-80	40	4.0	19	5.5
>80	42	4.2	15	4.4
Total	1 345	100	345	100
URINE ANALYSIS (DIPSTICK)				
Category	**Number**	**%**	**Number**	**%**
Normal	907	80.1	274	82.5
Abnormal	226	19.9	58	17.5
Total	1 465	100	332	100

A rash was noted in 15.4% of current employees, from either examination or history. Many attributed this to arsenic exposure. The final report will cover this issue in more detail. Blood lead levels were generally low (99.9% < 40 ug/dl). One individual had a blood lead > 60 µg/dl. He worked

in the "Oxygen plant unit". An investigation is required of possible occupational exposure to lead in this unit.

According to body mass index (BMI) 39.5% of current employees evaluated were either overweight or obese. Hypertension was graded according to the 2013 European Society of Hypertension and European Society of Cardiology Guidelines[4]. Hypertension was common in current employees: 29.3% had high blood pressure at examination with 9.9% in grade 3 - a substantial concern.

Table 8: Current and ex-employees by percentage loss of hearing (PLH)

	Current employee		Ex-employee	
Percentage loss of hearing category*	**Number**	**%**	**Number**	**%**
1.1 - 4.9	790	80.6	317	82.9
5 - 9.9	94	9.6	15	8.2
10 - 14.9	49	5.0	9	4.3
>15	47	4.8	15	4.6
Total	980	100.0	356	100

*PHL <1.1 excluded.

Table 8 shows the audiogram results by categories of percentage loss of hearing (PLH). Hearing loss was common with 96 current employees (9.8% of those tested) having PLH ≥ 10% which is a significant loss. Many of these persons did not have audiograms typical of noise induced hearing loss or had short period of employment at the NCS site. The final report will consider hearing loss in more detail.

SO_2 exposure, as reported by the employee and thus of uncertain reliability, was common as were symptoms reported to be associated with this exposure. Table 6 presents reported exposure and symptoms for current employees.

Table 9: Reported SO_2 exposure and associated symptoms in current employees

	Number	**%**
Reported exposure to SO_2	921	79.4
Any symptom associated with SO_2	785	85.2 (of those reporting exposure)
Respiratory symptoms associated with SO2	425	46.1 (of those reporting exposure)

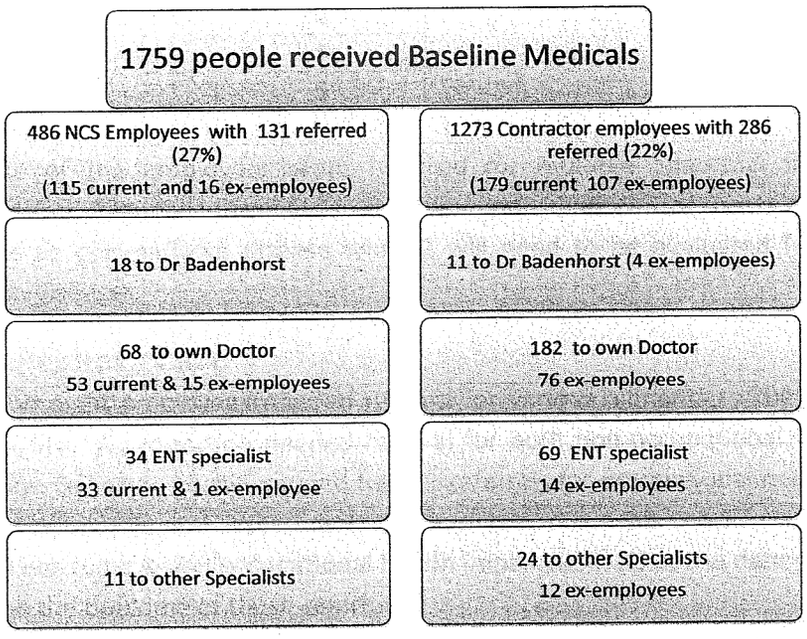
There was no association with decreasing median urinary arsenic concentrations and decreasing median ALT levels, as shown in Table 10. Current urinary arsenic levels are likely to be a poor surrogate for arsenic exposure over time and thus a poor variable for the exploration of ALT levels in relation to arsenic exposure.

Table 10: Median urinary arsenic levels (µg/g creatinine) and median ALT (IU/L) and 90th percentile ALT (IU/L) by Section in current employees

Department	**Median arsenic level**	**Median (ALT)**	**90th percentile (ALT)**
Arsenic Plant	309	25	66
Service Provider	168	24	69
Copper Smelter	165	32.5	72

Other	159	23	47
TLS Furnace	151	30	58
Slagmill	146	29	62
Material Handling	124	27	69
Engineering	111	27	52
Lab & Technical	105	28	74
Administration	55	30	46

Individuals who required referrals



The records show that a total of 355 employees needed referral to either specialists or their own doctor for acute medical conditions that needed further attention. The occupational medicine doctors filled in the referral forms – one copy was given to the employee and another copy left in the employee's file for the NCS occupational health nurse to facilitate the referral and follow up on the outcomes of the referrals.

A selected group of referrals was to a Tsumeb occupational medical practitioner (Dr Badenhorst) who was requested to assess employees that were possibly occupational in causality and to exclude non-occupational causes and also to prepare them for review by the ophthalmologist, dermatologist, neurologist or physician. The criteria for referral to Dr Badenhorst included those who had a cumulative exposure to arsenic of at least 3 years; skin or eye problems; abnormal liver function tests and low haemoglobin.

Quite a large group had abnormal audiograms. Since this is a mixture of employees with occupational and non-occupational noise induced hearing loss including those that are currently exposed to noise and are at risk of developing hearing loss from current exposures, a decision was

made to manage these as a collective at company level. As such referrals to an ENT specialist or audiologist were deferred to a later stage once preliminary screening has been done at the company.

Referrals to Dr Badenhorst

A total of 43 employees were referred to Dr Badenhorst. Fourteen never came for assessment. Of the 29 that were assessed, 14 were finalised and 11 employees who were requested to come back for review did not honour their appointments. Four reports on these employees are still outstanding.

Table 11: Number of referrals by disease category

Liver abnormalities	24
Dermatology.	10
Ophthalmology	2
Abnormal Blood Results	4
Neurology	1
Chest pathology	5

Note that some of the employees were referred for multiple abnormal findings on clinical examination and / or diagnostic tests within the same individual. Out of the 14 that were finalized, 12 did not have an occupational disease while 2 will need to be evaluated further for possible occupational skin diseases.

Referrals to Primary Care

Two hundred and eight employees needed referral for various ailments to their own doctor or a public health facility. A proportion needed referral for both non-occupational and possible work-related conditions. Of these, 14 still needed further referrals for occupational noise induced hearing loss (NIHL); 5 for dermatological assessment; 13 for physician consult and 5 for ophthalmology. The rest were found not to have any occupational health impairment. As at the date of this report there is no feedback on the outcome of these referrals

Table 12: Number of referrals by type of health problems

Possible active pulmonary tuberculosis	11
Hypertension	56
Abnormal Liver Function Tests (positive social and medical history)	51
Abnormal Full Blood Count	55 (8 for anaemia)
Miscellaneous (diabetics, cardiac, abnormal urine dipstix or gastrointestinal problems)	35

Noise Induced Hearing Loss referrals

In total, 104 employees were identified with hearing loss. The employees had a combination of mixed hearing loss, unilateral hearing loss and abnormal audiograms for verification by a diagnostic audiogram.

These employees need to be categorised into occupational and non-occupational hearing loss. Current noise exposures need to be taken into account and an effort made to control noise

exposure. Those with occupational NIHL should be evaluated further for possible compensation. A policy has to be developed on how to deal with those with hearing loss that are still exposed to noise and also new recruits with previous hearing loss.

Potential employees with occupational disease

This section can only be finalised after all the reports of referrals have been received, evaluated and signed off by NIOH. We are waiting for a final list of possible occupational NIHL that will be referred for diagnostic audiogram and/or ENT.

Discussion and recommendations

This report presents preliminary findings from the evaluation of NCS current and former employees. A more detailed analysis is required to finalise the report. Nevertheless a number of issues have been identified which require a response.

1. Urinary arsenic levels were high showing widespread excessive absorption of arsenic. This problem is known to the NCS management, workers and occupational health service providers. NCS has committed to technological and engineering inputs to reduce exposure, but in the interim all workers with high urinary arsenic levels should be considered index employees prompting a workplace investigation of work procedures, sources of exposure, control measures and use of personnel protective equipment. The investigation should aim to identify remedial measures to control exposure. Respirator fit testing should be considered as part of this process. Urinary arsenic concentrations of greater than 300 µg/g creatinine in employees could be considered for the first phase of this approach; the high cut-off point could be lowered as control improves.

2. Skin rashes were common. A large proportion is likely to be the acute response to arsenic exposure. A systematic response is required. A treatment protocol should be developed with a dermatologist and resources for treatment made available at the worksite occupational health service. Employees should be informed of the service and it should be easily accessible to all employees on site, including contract workers. Each case of arsenic-associated rash should be investigated to identify failures in exposure control mechanisms.

3. Hearing loss was common. PLH is not the best method of categorising severity of loss and the final report will analyse hearing loss in more detail, but this is clearly an issue that requires attention. The hearing loss was a combination of non-occupational loss (for example past infections), noise induced hearing loss (NIHL) not due to exposure at NCS and NCS associated NIHL. A comprehensive hearing conservation programme is required. Diagnostic audiograms should be done on employees with PLH > 10% - if not already done - and compensation claims processed for employees with NIHL, irrespective of the attributable employer. Given the large numbers affected, it would probably be cost-effective to do the diagnostic audiograms on-site.

4. SO_2 exposure with associated symptoms was reported by a large proportion of surveyed employees. This was a subjective assessment and thus should be treated with caution. Nevertheless, it clearly warrants further objective assessment, including periodic

measurements of SO_2 in ambient air and control of exposures as indicated by measurements.

5. A number of non-occupational conditions were prevalent: overweight and obesity and hypertension being the most prominent. These conditions are, of course, of concern in the region as a whole. The workplace is recognised as an important setting for individual health promotion and NCS should consider workplace intervention's to manage these conditions.

Besides more detailed analyses, the final report will consider limitations of the survey methodology and cite the findings in the context of the literature.

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Table 13: Health effects of inorganic arsenic exposure

(Note that some of these health effects have only been described in communities drinking water contaminated with arsenic).

Acute and sub-acute		
Organ system	**Symptoms & Signs**	**Comments**
Gastrointestinal	Nausea, vomiting, anorexia, heartburn, abdominal pain, diarrhoea	Acute poisoning not expected in occupationally exposed cohorts
Dermal	Dermatitis, vesiculation	
Neural	Encephalopathy, neuritis, peripheral neuropathy (primarily sensory type)	
Renal	Cortical necrosis, leukocyturia, hematuria, oliguria, uraemia	
Hepatic	Congestion, fatty infiltration, central necrosis, acute yellow atrophy, cholangitis, cholecystitis	
Haematological	Anaemia, thrombocytopenia, leucopoenia, bone marrow suppression	
Cardiovascular	Cardiac abnormality (ventricular fibrillation and atypical tachycardia), congestive heart failure, hypotension	
Respiratory	Irritation of upper respiratory tract and bronchi, pulmonary oedema, bronchial pneumonia, nasal septum perforation	
Ophthalmic	Conjunctivitis	
Chronic		
Dermal	Hyperpigmentation with depigmentation, facial oedema, palmo-plantar hyperkeratosis, desquamation	
Gastrointestinal	Oesophagitis, gastritis, colitis, abdominal discomfort, anorexia, malabsorption, weight loss	
Neural	Hearing loss, symmetrical peripheral polyneuropathy (sensory-motor type), electromyographic abnormalities	Not well established for chronic exposure
Hepatic	Cirrhosis, hepatomegaly, portal hypertension without cirrhosis, fatty degeneration	Liver cirrhosis reported in copper smelters
Hematological	Bone marrow hypoplasis, aplastic anaemia, anaemia, leucopoenia, thrombocytopenia,	Less well established for chronic exposure
Respiratory	Rhino-pharyngo-laryngitis, trachea-bronchitis, chronic restrictive / obstructive disease	Weak evidence for lung function deficits
Metabolic	Diabetes mellitus	Suggestive evidence
Ophthalmic	Lens opacity	
Heart	Arrhythmias, pericarditis	
Peripheral artery	Blackfoot disease (gangrene with spontaneous amputation), Reynaud's syndrome	Reported mainly in Taiwan
Coronary artery	Ischemic heart disease	
Cerebral artery	Cerebral infarction	Evidence weak for cerebro-

		vascular disease
Atherosclerosis	Carotid atherosclerosis	
Blood pressure	Hypertension	
Microcirculation	Microcirculation abnormalities	

Source: Table modified from the Handbook on the Toxicology of Metals, Chapter 19, Third Edition. Eds Nordberg GF et al. Elsevier, 2007; with additional information from Environmental Health Criteria 224 Arsenic and Arsenic Compounds. Second Edition. International Programme on Chemical Safety. World Health Organization, 2001.