Total Bridge Services

Zinc Chromate Testing Summary

October 2009

Total Bridge Services
09 Princes Street
Northcote Point
Auckland, New Zealand
Telephone: +64 9 481 0078
Facsimile: +64 9 481 0079

Date: 20 November 2009

Prepared by: **Total Bridge Services**

Index

1 Identifying an Issue with Zinc Chromate on the Bridge 3

2 Further Investigation into Chromium Exposure 4

3 Responses to the Report 5

3.1 Urine Testing 5

3.2 Additional Measure to Minimise Exposure 5

3.3 Follow-up Testing 5

Appendix 1 6

Appendix 2 7

1 Identifying an Issue with Zinc Chromate on the Bridge

Zinc chromate paint was used as the principle primer on the external surfaces of the AHB until 1994, when it was recommended that the primer be substituted with a less toxic equivalent. The hazards associated with zinc chromate paint had previously been identified as a potential issue for the abrasive blasting crews working on the bridge. Urine testing for zinc chromate was carried out over a period of two years, from 2003 to 2004 with the maintenance crew. All the results came back well below detectable levels for testing. It was subsequently concluded that zinc chromate was not a significant hazard on the bridge and provided that the correct PPE was worn during blasting operations, the testing could cease.

2 Further Investigation into Chromium Exposure

In April of this year, the zinc chromate issue on the bridge was revisited after a paper was published about the dangers of occupational exposure to hexavalent chromium. The paper indentified that the safe exposure levels for chromium were significantly lower than those for lead and that the toxicity level was significantly higher. This was cause for concern, due to the fact that there had been major problems with lead paint removal and contamination during the commencement phase of the BGS project. Total Bridge Services already had a comprehensive health monitoring programme for lead screening of all bridge workers, however no chromate testing had been carried out since 2004.

As a result, Total Bridge Services initiated a full investigation into the possible chromate issue on the bridge, engaging the services on Paragon Health and Safety Consultants. Swab samples were taken from areas believed to be a possible risk to personnel and bridge users and air monitoring was carried out around blasting operations to ascertain whether there was a risk of exposure to hexavalent chromium. The final report concluded that there was a risk of exposure to hexavalent chromium on the bridge, particularly for the blasting crews. It was recommended that Total Bridge Services carry out urine testing on all the maintenance crew to investigate their possible exposure and a review of the controls to minimise exposure to the hazard during blasting operations.

3 Responses to the Report

3.1 Urine Testing

Urine tests for chromium were carried out on a weekly basis from the 16th July to 27th August 2009. A total of 25 people from the bridge maintenance crew were tested a minimum of four times each, during the testing period. Testing was carried out on Thursdays around midday so there was at least three days of possible exposure before the samples were taken. Work activities were also recorded for each employee, in case there was a need to track what operations were causing elevated levels.

The standard for the maximum allowable level of exposure is 30µg of chromium per litre of urine and the minimum detectable level for the laboratory is 2µg/L. All the test results received during the testing period came in at less than 2µg of chromium per litre of urine. The results were a clear indication that the maintenance crews were being exposed to negligible levels of chromium.

3.2 Additional Measure to Minimise Exposure

In addition to the chromate screening programme, other measures were implemented or improved to reduce the risk of chromium exposure in the blasting crews. A high standard of PPE use and hygiene requirements were put in place, including additional wash facilities, better storage of blasting gear, use of disposable overalls and re-education of staff in good hygiene practice and maintenance of PPE.

Options for wet blasting were also investigated and appraised by the TBS coatings expert in an effort to contain dust prior to it becoming airborne. The urine test results over the 6 week period are a clear indication that the PPE and hygiene measures that have been put in place, provide sufficient protection against exposure to chromium.

3.3 Follow-up Testing

It was subsequently decided that a sample of works crews, with the highest potential for exposure to zinc chromate, would be periodically re-tested.

The intention is to test a sample of four people, approximately every 6 months. Tests will be carried out at the end of a week of where the crews have primarily been carrying out sand blasting operations. On this basis, test periods would fall in February-March and August-September each year.

Appendix 1

Occupational Hygiene Assessment
Exposure to Hexavalent Chromium Report

PARAGON
HEALTH & SAFETY CONSULTANTS

OCCUPATIONAL HYGIENE ASSESSMENT

Exposure to Hexavalent Chromium

Total Bridge Services

Assessor: Ian Bartlett MFOH
Registered Occupational Hygienist

Project Ref: ib0509-01
Issue 1: 7th July 2009

Authorised Copies:
Jon Patman – Project Engineer – TBS
File - Paragon Health & Safety

PO Box 19679 | Avondale | Auckland | New Zealand
Tel: 09 813 2291 | Fax 09 813 2261 | Mobile 025 272 8038
Email: ian@paragonhs.co.nz | www.paragonhs.co.nz

EXECUTIVE SUMMARY

Air and surface wipe sampling was undertaken to determine the airborne concentration of hexavalent chromium, from abrasive blasting processes on the Auckland Harbour Bridge, to which some operators and others may be exposed.

The results indicate that hexavalent chromium was detectable in both the air samples and the surface wipe samples.

Some airborne concentrations and some settled dust deposits were significant from an exposure perspective.

Recommendations are made for the ongoing management and control arising from these exposures.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

1. INTRODUCTION 1

2. BACKGROUND 1

2.1 PROCESS DESCRIPTION 1
2.2 OPERATING CONDITIONS DURING ASSESSMENT 3

3. ASSESSMENT OF EXPOSURES 4

3.1 SAMPLING & ANALYSIS METHODOLOGY 4
3.2 WORKPLACE EXPOSURE STANDARDS 5
3.3 AIR SAMPLING RESULTS 6
3.3.1 Discussion – Air sampling results 7
3.4 WIPE AND BULK SAMPLING RESULTS 8
3.4.1 Discussion – Wipe and Bulk samples 9
3.4.2 Discussion – Air, Wipe and Bulk samples in the context of skin absorption 10

4. SUMMARY OF HEALTH EFFECTS 10

5. CONCLUSIONS 12

6. RECOMMENDATIONS 13

7. SIGN OFF 15

8. SIGNIFICANT REFERENCE SOURCES 15

Appendix 1 – Hexavalent Chromium essentials 16

Definitions & abbreviations	
Ceiling	Workplace Exposure Standard – Ceiling (WES-Ceiling). *A concentration that should not be exceeded during any part of the working day.*
Hexavalent chromium	Hexavalent chromium
mg/m^3	Milligrams per cubic metre – a measure of the concentration of a substance in the atmosphere on a mass/volume basis
MSDS	Material Safety Data Sheet
OSH	Occupational Safety & Health Service - Dept of Labour
15 min STEL	Workplace Exposure Standard – Short Term Exposure Limit (WES-STEL). *The 15-minute average exposure standard.* Applies to any 15-minute period in the working day and is designed to protect the worker against adverse effects of irritation, chronic or irreversible tissue change, or narcosis that may increase the likelihood of accidents. The WES-STEL is not an alternative to the WES-TWA; both the short-term and time-weighted average exposures apply.
15 min GEL	Often there is insufficient toxicological data available for the establishment of a Short Term Exposure Limit. Peak exposure should however still be controlled even in situations where the Time-Weighted Average level is not exceeded. A 15-minute exposure limit of three times the TWA is recommended. Where a STEL has been assigned, the STEL value takes precedence over the general excursion regardless of whether or not it is a stricter standard.
8hr TWA	Workplace Exposure Standard – Time Weighted Average (WES-TWA). The time-weighted average exposure standard designed to protect the worker from the effects of long-term exposure.
PPE	Personal Protective Equipment
WES	Workplace Exposure Standard – a figure published by OSH (Dept of Labour) which gives guidance on acceptable levels of some contaminants in the workplace.

1. INTRODUCTION

This report sets out the results of an assessment to determine personal exposures to hexavalent chromium hexavalent chromium during maintenance and recreational activities on the Harbour Bridge, Auckland. This report relates to the processes as they were at the time of the assessment.

The site work was carried out by Ian Bartlett on 28th May, 4th 5th and 6th June 2009 and the results and this report were finalised by Ian Bartlett.

Ian Bartlett is a Registered Occupational Hygienist with Paragon Health & Safety.

2. BACKGROUND

Total Bridge Services are responsible for the maintenance of the Auckland Harbour Bridge. Various maintenance activities can involve abrasive blasting of various parts of the bridge structure.

Historically anti-corrosion, chromate based paint primers (zinc chromate) have been used on the bridge structures. During abrasive blasting airborne particulates are released which will comprise the blasting media (garnet), paint layers (both primers and top coats) and probably small amounts of metal particulates from the steel structure.

A fraction of the airborne particulates will be as paint particulates and hexavalent chromium is an expected component..

2.1 PROCESS DESCRIPTION

The personnel who may be exposed include (in descending order of expected most highly exposed) are:

- Abrasive blasting operators.
- Maintenance workers employed on other tasks in the vicinity of blasting operations
- Maintenance workers who come into contact with settled dusts on the bridge
- Those involved with handling overalls and equipment used in abrasive blasting
- Maintenance workers transiting past an abrasive blasting area
- Bungy & Bridge Walk personnel
- Bungy & Bridge Walk participants (clients)

This monitoring exercise investigates the extent to which hexavalent chromium may be dispersed and deposited as a result of abrasive blasting operations.

Abrasive blasting can take place on most parts of the bridge structures.

Dispersal of particulates will largely be a factor of

- The degree to which the blasting operation is enclosed
- Wind speed and direction
- Bridge structures affecting wind direction and speed
- Bridge structures in the path of particulate 'cloud'

For this study an abrasive blasting operation underneath the bridge structure was chosen as this would likely represent a 'worst case' scenario.

The photograph below illustrates the operation.

Photo 1 Area of bridge structure for abrasive blasting

The yellow arrow indicates the area of the bridge structure from which paint was abraded. A similar area was abraded on the other side of the support beam. Blasting takes place with two operators working on a beam each, at either end of the travelling work platform.

Photo 2 Gaps in bridge structure through which dust cloud penetrates

In the above photo one of the two blasting operators (yellow arrow) can be seen working on the beam. The other operator is out of picture to the left. There are many gaps between the bridge structure (blue arrows) through which dust particles can penetrate. These particles can also impinge and deposit on the surrounding structures.

2.2 OPERATING CONDITIONS DURING ASSESSMENT

On the days of sampling the work progressed along the length of the bridge.

Throughout the work access to the bridge walkways was unrestricted for both TBS personnel and those involved in the recreational activities.

The weather was dry, with broken cloud and extended periods of sunshine.

On the first sampling day (4th June) wind conditions were near calm.

On the second sampling day (6th June) wind conditions were a light breeze from the south west.

3. ASSESSMENT OF EXPOSURES

3.1 SAMPLING & ANALYSIS METHODOLOGY

Air Sampling Methodology

The basic method follows the National Institute of Occupational Safety and Health (NIOSH) Method 7600 for hexavalent chromium. To summarise, a 25mm diameter 5µm pore size PVC filter was mounted in an IOM inhalable dust sampling head and attached to a personal sampling pump by way of flexible tubing. The sampling assembly was placed in an area of interest and a air was drawn through the filter for a known period of time at 2.0l/min to trap any aerosols that may be present. The samples were then sent to an independent analytical laboratory where they were digested with a hot carbonate solution under nitrogen. The final solution from each sample was analysed for total hexavalent chromium using visible absorption spectrophotometry. Analytical results and the sample volume are then used to calculate the concentration of hexavalent chromium in the atmosphere as mg/m^3.

Surface Wipe Sampling Methodology

The basic method follows the Occupational Safety and Health Administration (OSHA) Method W4001 for wipe samples where hexavalent chromium is the target compound. To summarise:

Chromate Check™, direct reading swabs were used to identify surfaces that carried detectable amounts of hexavalent chromium. This was determined by a colour change in the swab from white to pink. The swab chemistry is specific for hexavalent chromium.

Once identified as being positive for hexavalent chromium a portion of a Ghost Wipe (approximately $900mm^2$) was wiped across a 100cm2 area of the surface of interest. The Ghost Wipe samples were then sent to an independent analytical laboratory where they were digested with a hot carbonate solution under nitrogen. The final solution from each sample was analysed for total hexavalent chromium using visible absorption spectrophotometry. Analytical results and the sample area are then used to calculate the concentration of hexavalent chromium on the surface as $\mu g/cm^2$.

Bulk Sampling Methodology

The basic method follows the Occupational Safety and Health Administration (OSHA) Method W4001 for wipe samples where hexavalent chromium is the target compound. To summarise, a sample of the material of interest was taken directly and put into a polystyrene petri dish. The samples were then sent to an independent analytical laboratory where they were digested with a hot carbonate solution under nitrogen. The final solution from each sample was analysed for total hexavalent chromium using visible absorption spectrophotometry. Analytical results then used to report the µg amount of hexavalent chromium in the sample. The results are indicative only of the presence of hexavalent chromium.

3.2 WORKPLACE EXPOSURE STANDARDS

Workplace Exposure Standards are endorsed by the Occupational Safety and Health Service (OSH). They are designed to protect the health of people at work who are exposed to hazardous substances such as chemicals, dust, fumes etc.

> *An exposure standard represents an airborne concentration of a particular substance in the workers breathing zone, exposure to which, according to current knowledge should not cause adverse health effects nor cause undue discomfort to nearly all workers. Compliance with the designated value does not, however, guarantee protection from discomfort or possible ill-health outcomes for all workers. The range of individual susceptibility is wide and it is possible that workers will experience discomfort or develop occupational illness from exposure to substances at levels below the exposure standards.*

Workplace Exposure Standards are set out in the Department of Labour publication Workplace Exposure Standards 2002. They section are intended to be used as guidelines for those involved in occupational health practice and not used by untrained persons as a marker in determining "compliance".

In assigning the standards, defining a level that will achieve freedom from adverse health effects is the major consideration.

The workplace exposure standards are not to be used to differentiate between exposure levels that are safe for all workers and those that are inherently hazardous.

Regardless of the standard, it is important to take all reasonable steps to reduce the concentration of airborne substances to the lowest practicable level.

While substances hazardous to health may enter the body following inhalation, ingestion or skin absorption, it is usually the inhalation component that is most important.

Some substances are known to have the potential for respiratory or skin sensitisation and the Workplace Exposure Standards are not always established with sensitisation as an endpoint for protection and while maintaining exposures below the Workplace Exposure Standards may reduce the risk of respiratory sensitisation doing so does not have any bearing on dermal sensitisation potentials.

Exposure to airborne substances is usually measured directly with personal air sampling techniques.

The Workplace Exposure Standard for hexavalent chromium in air is 0.05mg/m^3 for both water soluble and insoluble species.

When the total exposure during the workday is potentially greater than 8 hours e.g. when a 12 hour shift is worked an adjustment is made to the Workplace Exposure Standard by applying the following formula based on the Brief and Scala Model.

$$\text{Adjusted WES-TWA} = \frac{8 \times (24\text{-h}) \times \text{WES-TWA}}{16 \times h}$$

This accounts for the extra 4 hours of potential exposure and the 'loss' of 4 hours of non exposure where the body has a chance to 'clear' any absorbed contaminant.

The 12 hour adjusted Workplace Exposure Standard for hexavalent chromium in air is 0.025mg/m^3

Published standards for acceptable concentrations of hexavalent chromium on surfaces were not discovered in spite of extensive searches of literature in the public domain.

Notes:

*1) A **WES-TWA** is an 8-hour time weighted average exposure standard designed to protect the worker from the effects of long-term exposure.*

3.3 AIR SAMPLING RESULTS

The results of the air sampling are shown below.

The airborne concentrations quoted in the following results are applicable only to the period of sampling. When interpreting the results it should be remembered that they are from two days sampling only. Variations in exposure levels will occur from day to day due to changes in work activities and seasonal and weather factors.

Air samples were taken in the following locations and illustrated in the photographs below:

Photo 3. Sampling location on mobile platform

Photo 4. Sampling locations on walkway

Sample No	Location	amount found ug	Time on hh:mm	total time min	Average flow l/min	Sample volume litres	Concentration mg/m3
TBSD186	Below walkway – 4/06/09❶	7.2	08:22	143	2.00	286.00	0.03
TBSD187	Level with walkway– 4/06/09❷	1.7	08:22	142	2.00	284.00	0.01
TBSD286	Below walkway - 6/06/09❶	28.2	11:52	150	2.00	300.00	0.09
TBSD287	Level with walkway - 6/06/09❷	9.1	11:52	150	2.00	300.00	0.03
TBSD2GNT	On mobile platform - 6/06/09	11.2	11:49	153	2.00	306.00	0.04

❶ = Photo 4 blue circle sampling head in 'free space' below pump but out of shot

❷ = Photo 4 red circle

3.3.1 Discussion – Air sampling results

a. It is to be noted that the samplers placed adjacent to the walkway were moved from time to time as the work progressed along the length of the bridge. The samplers were placed 'downwind' of the work so as to ensure that samples were taken from within the area where the spray drift was observed to approach and penetrate gaps in the bridge structures. Distances from the work platform ranged between 10m and 20m (approx).

b. Comparison of samples taken adjacent to the bridge walkway (TBSD186, TBSD187, TBSD286, TBSD286) indicates that there was a higher concentration of hexavalent chromium in the 'free air' than in the air that penetrates through the structural gaps. One likely reason for this is that the bridge structures impede the passage of some of the larger particles i.e. the structure acts as a coarse filter.

c. Comparison of samples taken adjacent to the bridge walkway (TBSD186, TBSD187, TBSD286, TBSD286) also indicates that there was a higher concentration of hexavalent chromium on the day when there was more wind. The most likely explanation is that on a calm day dispersion of the particles would more likely approach a spherical model whereas on a windier day the dispersion may be more conical and hence more concentrated.

d. The sample taken on the work platform needs careful interpretation. On Day 1 the sampler was worn by one of the operators. The overspray from the blasting process was heavy enough to virtually destroy the fragile PVC filter onto which the sample needs to be collected. In an attempt to overcome this, on Day 2 the sample head was located on the platform adjacent to the operator (Photo 3). It was observed that at the end of sampling there were 'pinhole' perforations in the filter. These pinholes were almost certainly caused through the high velocity of some larger particles that reach the filter. Additionally the blasting process produces sparks when the abrasive media reached bare metal. These sparks, if they reach the filter, will almost certainly melt the PVC from which the filter is made.

e. Given the discussion in d. above the result for the sample taken on the platform (TBSD2GNT) is considered to be an underestimate of the actual concentration of hexavalent chromium.

f. Although the sampling was carried out over approximately a 2½ hour period, the concentrations found can be considered to represent those that might be sustained over longer periods of time. Given that the Workplace Exposure Standard is 0.05mg/m3 as an 8 hour TWA the airborne concentrations measured are considered to be of occupational significance.

3.4 WIPE AND BULK SAMPLING RESULTS

The results of the surface and bulk sampling are shown below.

Samples were taken in the following locations and illustrated in the photographs below:

Photo 5. Sample top of screen housings TBSAJ1

Photo 6. Sample tubular pod frame TBSAJ2

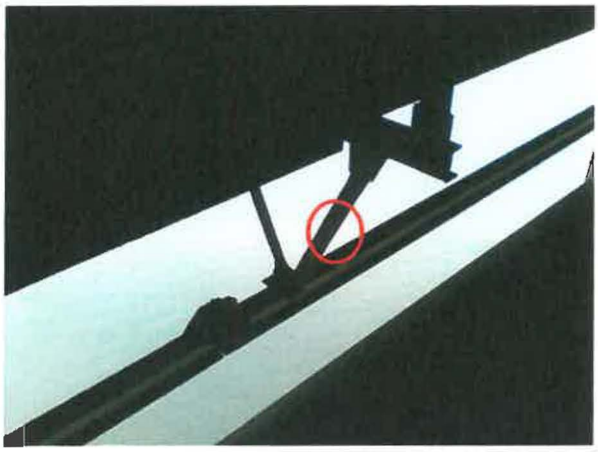

Photo 7. Samples TBSW1, TBSW2 & TBSW3

Photo 8. Sample TBSW4

Sample Number	Location	Surface Type	Description	Surface material	Surface treatment	Area sampled cm2	Amount Cr6 ug	Concentration ug Cr6/cm2
TBSW1	between 4-4 & 4-5	Metal Structure	Outer walkway V stay under walkway. Represents an area not within recent spraydrift.	Metal	Painted	100	0.8	0.008
TBSW2	between 5-9 & 5-10	Metal Structure	Outer walkway V stay under walkway. Represents an area within current day's spraydrift.	Metal	Painted	100	2.1	0.021
TBSW3	between 5-2 & 5-3	Metal Structure	Outer walkway V stay under walkway. Represents an area within previous day's spraydrift.	Metal	Painted	100	0.02	0.0002
TBSW4	between 5-2 & 5-3	Metal Structure	Seaward 'pipe' bearer. Sample taken from seaward surface. Represents an area within previous day's spraydrift.	Metal	Painted	200	40.3	0.2015
TBSW5	N/A	other	Overalls of assessor after having been in contact with various structures underneath bridge.	fabric	Untreated	100	28.2	0.282
TBSW6	N/A	other	Top of blasting helmet	Composite	Untreated	100	12.2	0.122
TBSAJ1	Bungy Pod	Shelf	BULK SAMPLE - Box above TV screens	Wood	Painted	N/A	0.4	N/A
TBSAJ2	Bungy Pod	Metal Structure	Behind framework of pod	Metal	Painted	N/A	0.1	N/A

Samples highlighted in red are deemed to be of significance.

3.4.1 Discussion – Wipe and Bulk samples

a. The results indicate that there is deposition of hexavalent chromium on bridge structures adjacent to blasting operations.

b. The process by which a sample is determined as being significant is essentially semi-quatitative and experience based. It is achieved by comparing sample results where hexavalent chromium might reasonably be expected with sample results where hexavalent chromium might not be expected. The latter is often taken as a 'background' i.e. a combination of ambient concentrations not related to specific activities and the limit of detection of the analytical method.

c. Of significance in the results above is the deposition demonstrated on a number of surfaces (samples TBSW2, TBSW4 & TBSW6) and how this deposition can be easily transferred to others not involved with the abrasive blasting process (TBSW5).

d. That sample TBSW3, represents an area that may have been affected by spray drift, yet did not show a significant deposition may indicate that the spray drift did not impinge on that part of the structure because of the drift direction of the dust cloud. Alternatively and or additionally it may be that the spray drift was of such a low concentration that hexavalent chromium was below the limit of detection for the method which would be estimated at around 0.4µg of hexavalent chromium on the Ghost Wipe.

e. That the samples taken from the Bungy pod did not show any significant amounts of hexavalent chromium is not unexpected. The pod structure itself would reduce ingress of most of the dust, especially when the pod 'jump door' is closed, and over time any hexavalent chromium would reduce to the trivalent form.

f. In the absence of any guidelines relating to surface contamination the assessment of the significance of surface samples is made with reference to the EPA reference dose (RfD) of 0.003mg/kg/day (3µg/kg/day). This means that an adult (body weight usually taken as 70kg) could absorb 3 x 70 = 210µg of hexavalent chromium before the reference dose would be exceeded. The RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure (oral intake) to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime.
g. In comparing the surface samples with the RfD it is to be noted that 100 cm2 (the sample area mostly used) is approximately the area of a hand print. Using the concentration of hexavalent chromium found on the assessors overalls the RfD would equate to 7.5 'hand prints'. The implication is that were all the hexavalent chromium to be transferred to the hands and then completely ingested and this were to be repeated around 8 times per day then the RfD could be exceeded. This scenario is considered to be very unlikely but it does reinforce the need for good personal hygiene, especially before eating.

3.4.2 Discussion – Air, Wipe and Bulk samples in the context of skin absorption

a. There are three main routes of absorption that need to be considered; inhalation, ingestion and skin absorption.
b. Ingestion has been discussed above and the air monitoring results suggest that, without appropriate precautions and/or controls, exposure via inhalation could exceed the Workplace Exposure Standard.
c. The airborne dust and the settled dust also have the potential to settle directly on the skin and be adsorbed.
d. Skin absorption is considered to be low but there is demonstrable uptake of hexavalent chromium via the skin (see Appendix 1).
e. Whilst the uptake rate may not be significant from a systemic toxicity viewpoint the potential for skin sensitisation remains and should not be overlooked.

4. SUMMARY OF HEALTH EFFECTS

The most concise summary of health effects is taken from the American Occupational Health and Safety (OSHA) Federal Register - Occupational Exposure to Hexavalent Chromium 71-10099-10385 - February 28, 2006 (Volume 71, Number 39)]

The health effects of exposure can be summarised as follows.

NB these summaries have been compiled from the OSH document.

Carcinogenic Effects

There has been extensive study on the potential for hexavalent chromium to cause carcinogenic effects, particularly cancer of the lung. OSHA reviewed epidemiologic data from several industry sectors including chromate production, chromate pigment production, chromium plating, stainless steel welding, and ferrochromium production. The evidence indicates that workers exposed to hexavalent chromium are at an increased risk of developing lung cancer

Non-cancer Respiratory Effects

The evidence clearly demonstrates that workers can develop impairment to the respiratory system such as nasal irritation, nasal ulceration, nasal perforation, and asthma. It is very clear from the evidence that workers may develop nasal irritation, nasal tissue ulcerations, and nasal septum perforations at occupational exposures level at or below 0.052$\mu g/m^3$. However, it is not clear what occupational exposure levels lead to the development of occupational asthma or bronchitis.

Dermal Effects

Occupational exposure to Hexavalent chromium is a well-established cause of adverse health effects of the skin. The effects are the result of two distinct processes:
(1) Irritant reactions, such as skin ulcers and irritant contact dermatitis, and
(2) delayed hypersensitivity (allergic) reactions.

Some evidence also indicates that exposure to Hexavalent chromium compounds may cause conjunctivitis.

The mildest skin reactions consist of erythema (redness), edema (swelling), papules (raised spots), vesicles (liquid spots), and scaling. The lesions are typically found on exposed areas of the skin, usually the hands and forearms. These features are common to both irritant and allergic contact dermatitis, and it is generally not possible to determine the etiology of the condition based on histopathologic findings.

Allergic contact dermatitis can be diagnosed by other methods, such as patch testing. Patch testing involves the application of a suspected allergen to the skin, diluted in petrolatum or some other vehicle. The patch is removed after 48 hours and the skin examined at the site of application to determine if a reaction has occurred.

Hexavalent chromium compounds can also have a corrosive, necrotizing effect on living tissue, forming ulcers, or "chrome holes". This effect is apparently due to the oxidizing properties of hexavalent chromium compounds. Like dermatitis, chrome ulcers generally occur on exposed areas of the body, chiefly on the hands and forearms (Ex. 35-316). The lesions are initially painless, and are often ignored until the surface ulcerates with a crust which, if removed, leaves a crater two to five millimeters in diameter with a thickened, hardened border. The ulcers can penetrate deeply into tissue and become painful. Chrome ulcers may penetrate joints and cartilage. The lesions usually heal in several weeks if exposure to hexavalent chromium ceases, leaving a flat, atrophic scar. If exposure continues, chrome ulcers may persist for months.

Other Health Effects

OSHA has examined the possibility of health effect outcomes associated with hexavalent chromium exposure in addition to such effects as lung cancer, nasal ulcerations and perforations, occupational asthma, and irritant and allergic contact dermatitis. Unlike the hexavalent chromium-induced toxicities cited above, the data on other health effects do not definitively establish hexavalent chromium-related impairments of health from occupational exposure at or below the previous OSHA Permitted Exposure Limit of 0.1mg/m^3.

5. CONCLUSIONS

Based on the results from this assessment and under the conditions existing at the time the following conclusions are made.

1. The results indicate that there are significant concentrations of hexavalent chromium in the spray drift resulting from the abrasive blasting process that requires control measures to keep personal exposures significantly below the relevant Workplace Exposure Standard.
2. The most likely adverse health effects to occur from these exposures are dermal effects and respiratory irritation or sensitisation. An elevated risk of a related lung cancer cannot be ruled out but, given the small population of those exposed, cases may not actually appear.
3. Exposure profiles are considered to be as follows:

Exposure Group	Exposure potential		
	Inhalation	**Dermal**	**Oral**
Abrasive blasting operators	**high**	**high**	**medium**
Maintenance workers employed on other tasks in the vicinity of blasting operations	**medium**	**medium**	**low**
Maintenance workers who come into contact with settled dusts on the bridge	**medium**	**medium**	**low**
Those involved with handling overalls or equipment associated with blasting processes.	**medium**	**medium**	**low**
Maintenance workers transiting past an abrasive blasting area	**low**	**low**	**low**
Bungy & Bridge Walk personnel	**very low**	**very low**	**negligible**
Bungy & Bridge Walk participants (clients)	**negligible**	**negligible**	**negligible**
NB. The exposure potential is not an estimation of risk. It is offered as a guide to where resources for control and management of exposures should be directed			

6. RECOMMENDATIONS

1. Further quantification of the airborne exposures to blasting operators should be considered. This is likely to require a modification to the blasting helmet enabling a sampling head to be used inside the helmet.
2. Personal protective equipment (PPE) must be stored and placed in such a way so as to prevent contamination of its surfaces that may come into contact with the skin. In particular (but not exclusively) this means that:
    a. gloves used during the abrasive blasting are not placed inside blasting helmets
    b. the smock. or collar of the blasting helmet is not turned inwards and tucked into the helmet
    c. other equipment that may be contaminated with paint or dust is not placed inside blasting helmets
    d. helmets and other PPE should not be left lying on the ground or in a position where the inside could become contaminated with dust
    e. facilities should be available at the site of blasting to enable hands to be cleaned should they become contaminated with dust.
3. Overalls must be laundered by a contracted company with facilities able to handle work wear contaminated with hexavalent chromium. The laundering contractor should be informed of the nature of the hazard.
4. Clothes worn under the overalls should be changed on a daily basis and also be laundered by a specialist facility.
5. Contaminated clothing and PPE should be segregated from non contaminated clothing and PPE.
6. A review of the design of the overalls used by those employed on abrasive blasting should be carried out. The aim of such a review is to determine if all practicable steps have been taken to provide clothing that prevents the ingress of dust containing hexavalent chromium onto the skin. Special features of such clothing would incorporate elasticated cuffs and no pockets on the outside of the clothing where dust could accumulate.
7. Similarly a review of the blasting helmet should be carried out to determine how easily the padded material inside can be removed and washed.
8. Blasting operators should shower and change into clean clothing, including footwear before leaving the worksite. Enough lockers should be provided to segregate clean clothing from work clothing.
9. Work clothing should not be taken home to wash.
10. The use of a dust cap worn underneath the blasting helmet should be considered as a meands to reducing dust contaminating the hair.
11. Eating smoking and drinking in the vicinity of an abrasive blasting process should be prohibited. Food, drink and cigarettes must not be taken into the blasting area wher they could become contaminated.

12. Prior to eating, drinking or smoking or entering a 'canteen/smoko area' contaminated overalls and hair covers should be removed, hands face neck and forearms should be washed and a clean pair of overalls worn. These overalls could be of a disposable kind.

13. Other maintenance workers who may come into contact with settled dust, especially where their work may be in restricted spaces requiring them to lie, crouch or crawl and/or wher the work would likely raise the settled dust should be wearing PPE and this may include the use of a disposable particulate respirator. A P1 mask is likely to suffice for most scenarios of this type.

14. Similarly for these workers points 3 – 12 raised above should be considered.

15. All tools and equipment likely to have become contaminated with hexavalent chromium should be identified as such and periodically cleaned down.

16. Where possible the use of 'drop cloths' to reduce the spread of the dust cloud from the abrasive blasting process should be a consideration during preparation for a job. This technique may be particularly useful where, for example
    - There may be adjacent 'sensitive areas' e.g. the Bungy Pod or video cabin
    - Other workers may be required to undertake tasks close to the blasting area

17. Wherever possible, areas subject to abrasive blasting debris or likely to have been contaminated with the debris should be thoroughly hosed down at the end of the day when blasting takes place.

18. Similarly where operators may be required to work in areas where there has been significant dust accumulation and their work is likely to expose them to large amounts of dust, the area should be hosed down prior to commencement of work. A considered assessment of the degree of exposure may need to be carried out as part of this decision making process.

19. Every effort should be made to exclude people from the areas where blasting is undertaken or where the spray drift may impinge. It is recognised that this may not always be possible and the exposure profiles set out in the Conclusions section can act as a guide.

20. Blasting operators and those undertaking tasks where they could come into significant amounts of settled dusts should be under Medical/Health surveillance. Such surveillance should be developed by a doctor holding a post graduate qualification in occupational medicine (eg. one holding membership of the Australian Faculty of Occupational Medicine [AFOM]). OSHA use 30 days of exposure at or over the Workplace Exposure Standard (in the US a PEL of 0.003mg/m^3) as a trigger point for when Medical/Health Surveillance is appropriate. In the TBS situation this would almost certainly encompass all those directly employed as blasting operators.

21. Consideration should be given to the following when planning Medical/Health Surveillance
    - Baseline medical checks and tests
    - Lung Function tests
    - Skin health checks

22. Allied to the Medical/Health surveillance programme all operators who are likely to be exposed to hexavalent chromium should have education and training in the basics of the various issues and control measures.

-----Ends-----

7. SIGN OFF

This independent assessment report has been prepared by Paragon Health & Safety Ltd for TBS.

The report reflects the position concerning exposure to hexavalent chromium arising from an abrasive blasting operation.

The Health and Safety in Employment Act requires that employees be informed of these results.

Conclusions and recommendations contained in this report are believed to substantially reflect good occupational hygiene and health practice, the current state of knowledge of the issues and the relevant legislative requirements.

This report is issued under the authority of

Ian Bartlett. BSc. DipOccHyg. SRN. MFOH.
Registered Occupational Hygienist
Author
7th July 2009

NB:	Original Copies. Unless otherwise stated this is only an original copy of this report if it signed and carries the Paragon logo, in colour on all pages.

8. SIGNIFICANT REFERENCE SOURCES

Health & Safety in Employment Act 1992

The Health and Safety in Employment Regulations 1995

Approve Code of Practice – Management of Substances Hazardous to Health. (pub. OSH)

Workplace Exposure Standards - Effective from 2002 - OSH New Zealand

Toxicological Review Of Hexavalent Chromium (CAS No. 18540-29-9) In Support of Summary Information on the Integrated Risk Information System (IRIS) August 1998 U.S. Environmental Protection Agency Washington, DC

Appendix 1 – Hexavalent Chromium essentials

The most common forms are chromium (chromium (0)), trivalent (chromium (III)), and hexavalent (chromium(VI)). Chromium(III) occurs naturally in the environment and is an essential nutrient required by the human body to promote the action of insulin in body tissues so that sugar, protein, and fat can be used by the body. Chromium(VI) and chromium(0) are generally produced by industrial processes.

Some hexavalent compounds, such as chromium(VI) oxide (or chromic acid), and the ammonium and alkali metal salts (e.g., sodium and potassium) of chromic acid are readily soluble in water. The alkaline metal salts (e.g., calcium, strontium) of chromic acid are less soluble in water.

The hexavalent chromium compounds are reduced to the trivalent form in the presence of oxidizable organic matter. However, in natural waters where there is a low concentration of reducing materials, hexavalent chromium compounds are more stable.

Transformation of chromium (VI) to Chromium (III)

The following commentary on the transformation of chromium(VI) to chromium(III) is taken from the document "Toxicological Profile For Chromium: U.S. Department Of Health And Human Services Public Health Service: Agency For Toxic Substances And Disease Registry: September 2000

Transformation in air

In the atmosphere, chromium(VI) may be reduced to chromium(III) at a significant rate by vanadium (V_{2+}, V_{3+}, and VO_{2+}), Fe_{2+}, HSO_{3-}, and As_{3+}. The estimated atmospheric half-life for chromium(VI) reduction to chromium(III) was reported in the range of 16 hours to about 5 days (Kimbrough et al. 1999).

Transformation in water

The reduction of chromium(VI) by S_{-2} or Fe_{+2} ions under anaerobic conditions was fast, and the reduction half-life ranged from instantaneous to a few days. However, the reduction of chromium(VI) by organic sediments and soils was much slower and depended on the type and amount of organic material and on the redox condition of the water. The reaction was generally faster under anaerobic than aerobic conditions. The reduction half-life of chromium(VI) in water with soil and sediment ranged from 4 to 140 days (Saleh et al. 1989).

Transformation in soil

The fate of chromium in soil is greatly dependent upon the speciation of chromium, which is a function of redox potential and the pH of the soil. In most soils, chromium will be present predominantly in the chromium(III) state. Under oxidizing conditions chromium(VI) may be present in soil as $CrO_{4\,-2}$ and $HCrO_{4-}$ (James et al. 1997). In this form, chromium is relatively soluble, mobile, and toxic to living organisms. In deeper soil where anaerobic conditions exist, chromium(VI) will be reduced to chromium(III) by S_{-2} and Fe_{+2} present in soil.

The reduction of chromium(VI) to chromium(III) is possible in aerobic soils that contain appropriate organic energy sources to carry out the redox reaction. The reduction of chromium(VI) to chromium(III) is facilitated by low pH (Cary 1982; EPA 1990b; Saleh et al. 1989). From thermodynamic considerations, chromium(VI) may exist in the aerobic zone of some natural soil.

The microbial reduction of chromium(VI) to chromium(III) has been discussed as a possible remediation technique in heavily contaminated environmental media or wastes (Chen and Hao 1998). Factors affecting the microbial reduction of chromium(VI) to chromium(III) include biomass concentration, initial chromium(VI) concentration, temperature, pH, carbon source, oxidation-reduction potential and the presence of both oxyanions and metal cations. Although high levels of chromium(VI) are toxic to most microbes, several resistant bacterial species have been identified which could ultimately be employed in remediation strategies (Chen and Hao 1998).

Elemental iron, sodium sulfite, sodium hydrosulfite, sodium bisulfite, sodium metabisulfite sulfur dioxide and certain organic compounds such as hydroquinone have also been shown to reduce chromium(VI) to chromium(III) and have been discussed as possible remediation techniques in heavily contaminated soils (James et al. 1997; Higgins et al. 1997). The limitations and efficacy of these and all remediation techniques are dependent upon the ease in which the reducing agents are incorporated into the contaminated soils.

Patch Testing

The following commentary on patch testing is taken from the document "Toxicological Profile For Chromium: U.S. Department Of Health And Human Services Public Health Service: Agency For Toxic Substances And Disease Registry: September 2000:-

A study was performed on 54 volunteers who were sensitive to chromium-induced allergic contact dermatitis to determine a dose-response relationship and to determine a minimum-elicitation threshold concentration (MET) that produces an allergic response in sensitive individuals (Nethercott et al. 1994). Patch testing was performed on the subjects in which the concentration of potassium chromate(VI) was varied up to 4.4 µg chromium/cm^2. Two percent (1/54) had a MET of 0.018 µg/cm^2 about 10% were sensitized at 0.089 µg/cm^2 and all were sensitized at 4.4 µg/cm^2.

Skin Absorption

The following abstract is from the 35th Annual Meeting of the Society of Toxicology and published in The Toxicologist Vol. 30, No.1, Part 2 March 96

Dermal Uptake of Hexavalent Chromium in Human Volunteers. Measures of Systemic Uptake from Immersion in Water at 22 ppm

J J J Clark[1], G E Corbett[1], B 0 Kerger[1], B L Finley[2] and D J Paustenbach[2]•

[1] McLareniHart-ChemRisk, Irvine, CA; [2] McLareniHart-ChemRisk, Alameda,CA

This study examines the systemic uptake of chromium in four human volunteers following 3 hours of contact with water containing hexavalent chromium [Cr(VI)] at a concentration of 22 ppm (mg/L). Volunteers were immersed below the shoulders (about 13,000 cm^2) in the water at 91 ± 2.5 0 F. On the day prior to the experiment and for six days afterwards, samples of urine, plasma, and red blood cells were collected and analyzed for total chromium. Red blood cell chromium concentrations were used as a specific biomarker for systemic uptake of hexavalent chromium. No sustained elevation of chromium concentrations was observed in red blood cells of the volunteers tested; thus, no appreciable Hexavalent chromium was systemically absorbed. Small increases were observed in the concentration of chromium in urine within 48 hours of exposure, indicating some Cr(III) may have penetrated the skin at a rate of about 3.5×10^{-5} to 5.2×10^{-4} µg/cm^{2-hr}. In short, dermal exposure of humans for 3 hours at 22 ppm Hexavalent chromium did not result in systemic uptake of measurable amounts of Hexavalent chromium, but a very small quantity of chromium may have penetrated the skin where it was subsequently reduced to Cr(III) before systemic uptake and distribution.

Appendix 2

Urine Testing Results

Name	16-Jul	23-Jul	30-Jul	6-Aug	13-Aug	20-Aug	27-Aug
Individual 1		<2		<2	<2	<2	
Individual 2			<2	<2		<2	<2
Individual 3	<2	<2	<2	<2	<2	<2	
Individual 4		<2	<2	<2	<2	<2	
Individual 5		<2					
Individual 6			<2	<2			<2
Individual 7			<2	<2		<2	<2
Individual 8		<2	<2	<2			
Individual 9	<2	<2	<2	<2	<2		
Individual 10	<2						
Individual 11		<2	<2	<2	<2	<2	
Individual 12			<2	<2		<2	<2
Individual 13				<2	<2	<2	<2
Individual 14		<2	<2		<2		
Individual 15			<2	<2	<2	<2	
Individual 16			<2		<2	<2	
Individual 17	<2	<2	<2		<2		
Individual 18	<2	<2	<2		<2	<2	
Individual 19		<2					
Individual 20		<2			<2		
Individual 21		<2			<2		
Individual 22			<2	<2	<2	<2	
Individual 23	<2	<2	<2			<2	
Individual 24			<2				