Health Canada Santé Canada

Canada

Hexavalent Chromium: Development of a Guidance Value Protective of Cancer

Ivy Moffat, PhD - ivy.moffat@canada.ca

Senior Evaluator, Water Quality & Science Division
Water and Air Quality Bureau, Safe Environments Directorate, Healthy Environment and Consumer Safety Branch, Health Canada

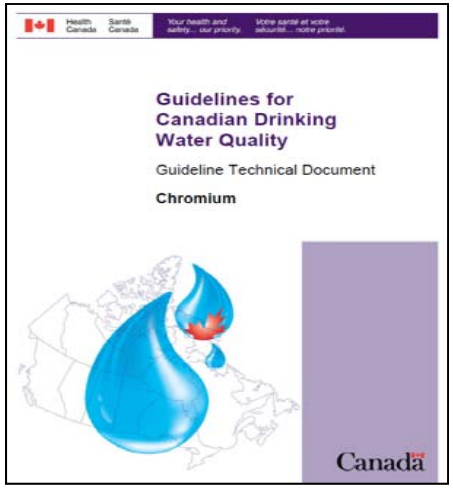
North Carolina Science Advisory Board (SAB)
August 20, 2018

YOUR HEALTH AND SAFETY... OUR PRIORITY.

Today's Agenda

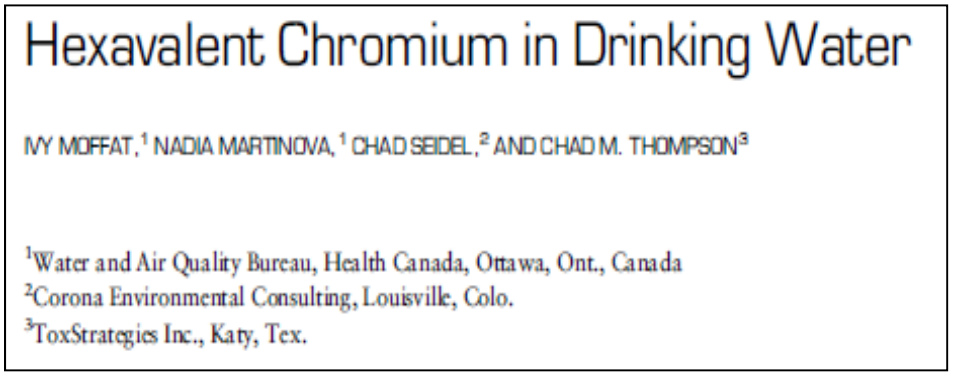
1. Overview of chromium's guideline development process
2. Critical information to derive the health based value (HBV)
3. Derivation of the HBV for chromium in drinking water
4. Comparison of risk assessment approaches

Based on:



Approved March 2016; Available online August 17, 2018

https://www.canada.ca/en/health-canada/services/environmental-workplace-health/reports-publications/water-quality.html#guidance



Hexavalent Chromium in Drinking Water

IVY MOFFAT,[1] NADIA MARTINOVA,[1] CHAD SEIDEL,[2] AND CHAD M. THOMPSON[3]

[1]Water and Air Quality Bureau, Health Canada, Ottawa, Ont., Canada
[2]Corona Environmental Consulting, Louisville, Colo.
[3]ToxStrategies Inc., Katy, Tex.

Moffat et al. May 2018, Journal AWWA 110:5

1. Chromium Guideline Development Process

Priority Setting

Risk Assessment:

- Independent contractor provided a review of all available science
- 2 senior evaluators conducted risk assessment
- Treatment & analytical considerations included

Peer review (*EPA, OEHHA, Summit Toxicology & internally*)

F/P/T committee on drinking water (CDW) review, impact & approval

Public consultation

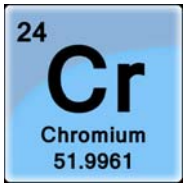
CDW review, impact considerations & approval

Extensive review process

CHE & HC approval
Publication

2. What is the critical information to derive a health based value (HBV) for chromium in drinking water ?

Critical Information to Derive a HBV for Chromium



Toxic moiety: Cr(VI)

- No definitive evidence of toxicity from Cr(III)exposure
- Cr(VI) “carcinogenic to humans” (group 1) based on sufficient evidence for carcinogenicity in humans (lung cancer) & sufficient evidence in experimental animals (IARC 2012)

Hazard ID: Diffuse hyperplasia of the small intestine

- 0.4 & 0.8 mg Cr(VI)/kg bw/day diffuse epithelial hyperplasia of small intestine (SI) in mice & histiocytic cellular infiltration of SI of rats respectively (NTP 2008)
- ≥1.4 mg Cr(VI)/kg bw/day SI tumors in mice (NTP 2008)
- 2.1 mg Cr(VI)/kg bw/day oral mucosal tumors in rats
- Environmental Cr(VI) levels are >1,000-fold lower than lowest concentration (5 mg/L) in the two-year cancer bioassay (a concentration that was not carcinogenic to mice or rats).

Critical Information to Derive a HBV for Chromium- Cont'd

Kinetics: Supports a threshold approach

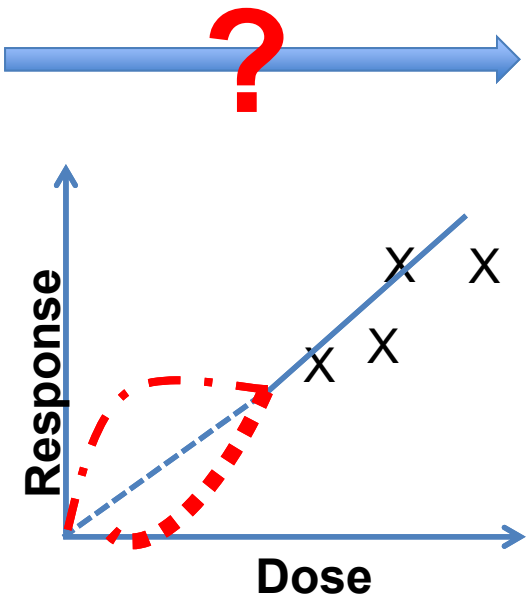
- Reduction, absorption & localization of chromium in the GI tract indicate several nonlinearities in Cr(VI) disposition.
- Depletion of reducing pools at high concentrations.
- Average Cr(VI) measurements (0.2–2 µg/L) in Canadian & US drinking water are within the reductive capacity of rodent & human gastric fluid.

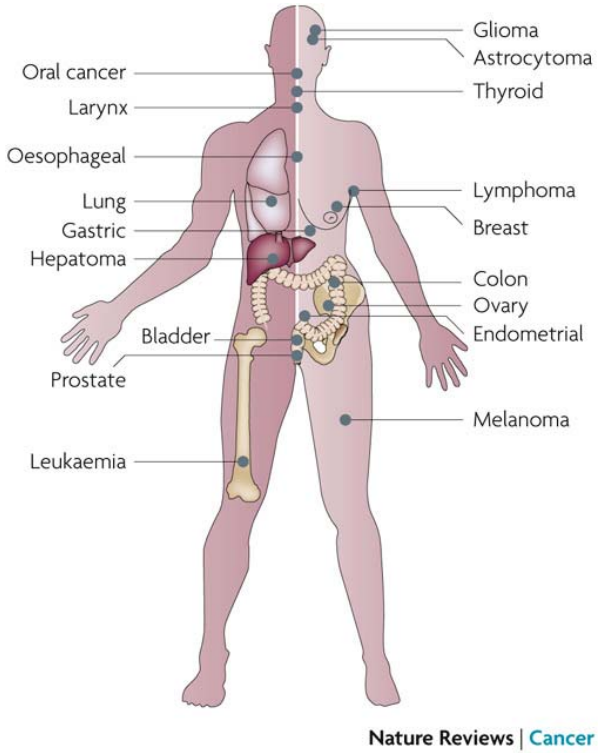
MOA analysis: Supports a threshold approach & is relevant to humans

- A nonmutagenic MOA of cytotoxicity leading to chronic regenerative hyperplasia (not a mutagenic MOA).

Linear or Threshold Risk Assessment Approach?

Intestinal hyperplasia & tumours

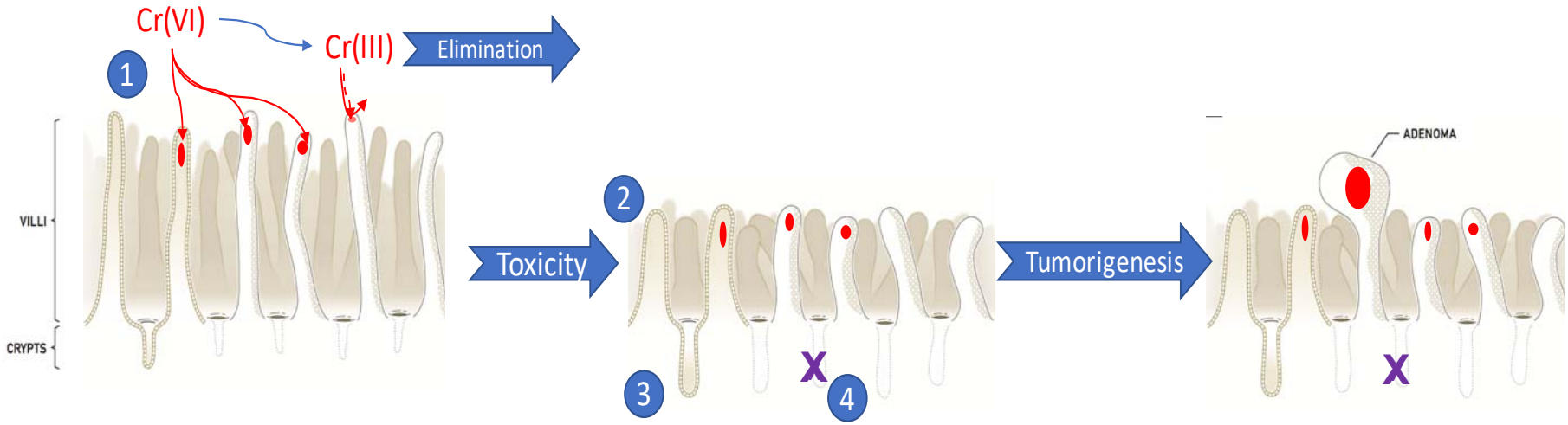




MOA analysis for intestinal carcinogenesis (Thompson et al. 2013)

- Based on an established MOA framework (Boobis et al. 2006, Meek et al. 2003).
- Reviewed by seven peer reviewers with expertise in MOA analysis provided by a science advisory board convened by an independent group (TERA 2012, 2009).

Mode of Action of Cr(VI)-Induced Intestinal Tumors in Mice



Low [Cr(VI)]: -Cr (VI) is reduced to Cr(III) by gastric & intestinal lumen fluid/contents;
-Cr(III) has minimal uptake relative to Cr(VI).

High [Cr(VI)]: the MOA has these key events:

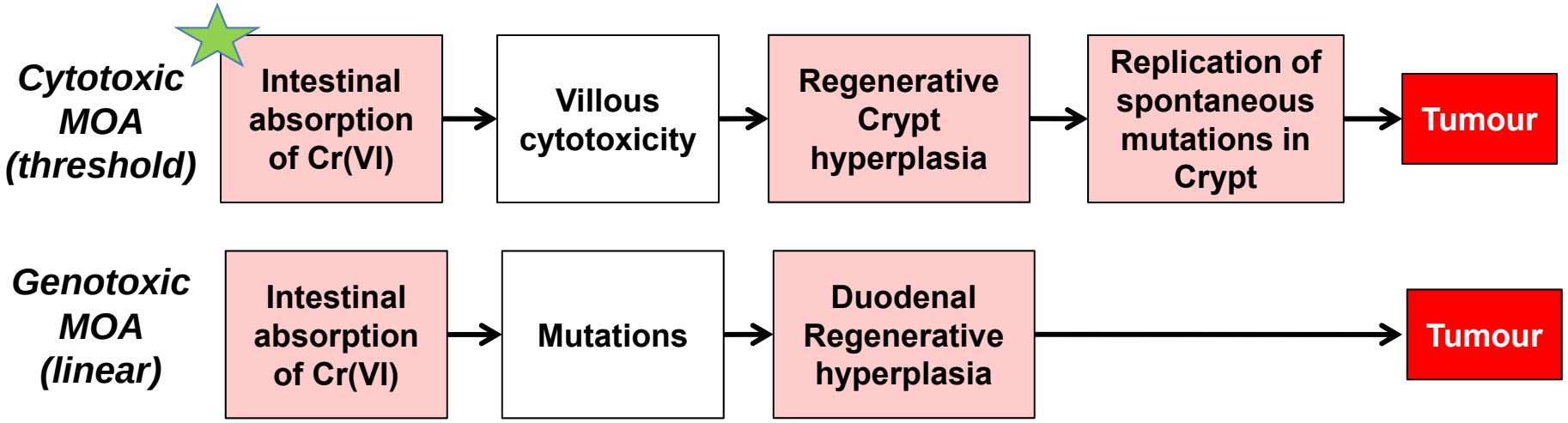
1. Unreduced Cr(VI) is available for absorption into villus enterocytes (red circles),
2. Cr(VI) causes cytotoxicity in villus enterocytes that can lead to villus blunting,
3. Crypt hyperplasia (note lengthening of the crypt depth) occurs to regenerate lost villus enterocytes,
4. Increased cell replication increases the chance of spontaneous mutation in intestinal crypt stem cells (indicated by **X**).

→ **Ultimately, chronic regenerative hyperplasia can lead to adenoma formation.**

→ **Based on analysis this MOA is relevant to humans.**

(Moffat et al. 2018, JAWWA 110:5)

Cytotoxic Vs. Genotoxic MOA



- ***Chromium likely not directly interacting with DNA:*** Chromium localized to intact intestinal villi (terminally differentiated cells) but not the crypt (proliferating cells).
- ***No genotoxicity in target tissues***
  - *in vivo* assays of intestinal tissues.
  - no genotoxicity in the oral cavity of rats which develop tumours (180 mg/L).
- ***Data do NOT fit the key characteristics for chemicals with a mutagenic MOA.***
- ***Data has strong tissue-relevant, dose-response & temporal concordance for a cytotoxic MOA.***
- ***Precedent:*** cytotoxic MOA for captan/folpet induced intestinal tumours.

Thus, the weight of evidence supports a cytotoxic MOA for Cr(VI)

(Moffat et al. 2018, JAWWA 110:5)

3. Derivation of the Health Based Value (HBV) for Chromium in Drinking Water

Toxic moiety: Cr(VI)
Key effect: SI hyperplasia is protective of cancer & non-cancer effects
Approach: Threshold approach is appropriate for risk assessment

$$HBV = \frac{(POD/UF)\ BW \times AF}{WC} = \frac{0.0022\ mg/kg\ bw/d \times 70\ kg \times 0.5}{1.5\ L} = \mathbf{0.05\ mg/L}$$

Point of Departure (POD): human equivalent dose (HED) 0.054 mg/kg bw per day ($BMDL_{01}$ & PBPK modeling).
Uncertainty Factor (UF) 25:

- × 2.5 for interspecies variability (PBPK models for kinetic differences);
- × 10 for intraspecies variability.

Body Weight (BW) 70kg: Average adult Canadian body weight.
Allocation factor (AF) 0.5: Based on exposure analysis; refers to the contribution of drinking water to the estimated total daily intake for Canadians.
Water Consumption (WC) 1.5 L: is the daily average volume of drinking water ingested by an adult. Dermal & inhalation exposure during bathing/showering are NOT significant.

4. Risk Assessment of Total Chromium in Drinking Water

(*Internationally regulated values 50-100 µg/L)*

Source	Key Endpoint / Modeling Parameters	Approach	Point of Departure *mg/kg bw/day*	Uncertainty Factors (UFs)
Health Canada 2015	Diffuse epithelial hyperplasia (NTP 2008); modeled duodenum and jejunum of male and female mice	Threshold based on MOA analysis; used rodent and human PBPK models to convert internal mouse dose to human equivalent dose (Thompson et al. 2014, Kirman et al. 2013, Kirman et al. 2012); allocation factor 0.5[a]	For BMRs of 10, 5, and 1%, BMDLs are 0.14, 0.11, and 0.054, respectively	25 (UF_A2.5[b], UF_H10, UF_D not necessary)
Haney 2015, TCEQ 2015	Diffuse epithelial hyperplasia (NTP 2008); modeled duodenum of female mice only	Threshold based on MOA analysis; duodenal doses in mice were obtained from experimental data (Kirman et al. 2012) and used for BMD modeling	BMR 10%: BMDL 0.31	100 (UF_A10, UF_H10, UF_D 1)
Thompson et al. 2018	Diffuse epithelial hyperplasia (NTP 2008); modeled duodenum and ileum of male and female mice	Threshold based on MOA analysis; used rodent and human PBPK models to convert internal mouse dose to human equivalent dose (Kirman et al. 2017)	BMR 5%: BMDL 0.02	21.6 (EF_{AD} 3, EF_{HD} 3, EF_{HK} 2.4, UF_D not necessary[c])
IPCS 2013, ATSDR 2012	Diffuse epithelial hyperplasia (NTP 2008); modeled duodenum of female mice only	Threshold; MOA uncertain	BMR 10%: BMDL 0.094	100 (UF_A 10, UF_H 10, UF_D not used)[d]
WHO 1996	Carcinogenicity by the inhalation route	Linear; carcinogenicity by the inhalation route (provisional)		

(Moffat et al. 2018, JAWWA 110:5)

Health Canada Santé Canada

Canada

Acknowledgments

Health Canada

(Approved: 2016; Web posting: Aug. 17, 2018)

Science: Michelle Deveau, Richard Carrier, Michele Giddings

Policy: Veronique Morisset, Anne Vezina

Treatment: Nadia Martinova, France Lemieux

Federal-Provincial-Territorial committee on drinking water

Journal AWWA

(Moffat et al. 2018,110:5)

Chad Seidel - Corona Environmental Consulting

Chad Thompson - ToxStrategies

YOUR HEALTH AND SAFETY... OUR PRIORITY.

Health Canada Santé Canada

Canada

Thank you

Ivy Moffat
ivy.moffat@canada.ca

Water quality mailing list
https://www.canada.ca/en/health-canada/services/environmental-workplace-health/water-quality/mailing-list-water-quality-environmental-workplace-health.html