

Contents

Chapter 1 Medicinal Arsenic: Toxic Arsenic

1.1	The Element	1
1.2	Mineral Medicine	2
1.2.1	Theophrastus Philippus Aureolus Bombastus von Hohenheim, aka Paracelsus	6
1.3	Arsenic Eaters of Styria	7
1.4	Fowler's Solution	13
1.5	Acute Promyelocytic Leukemia (APL)	20
1.6	The Organoarsenicals	22
1.6.1	Robert Bunsen	22
1.6.2	Paul Ehrlich	24
1.6.3	The Golden Age of Organoarsenicals	28
1.6.4	African Sleeping Sickness	31
1.7	The Darker Side: Toxicity	33
1.8	Arsenicosis and Cancer	35
1.9	Biomarkers	38
1.9.1	Urine	38
1.9.2	Hair	39
1.9.3	Finger and Toe Nails	40
1.9.4	Saliva	40
1.10	Animal Models	41
1.11	Chelate Compounds and Chelating Agents	41
1.11.1	Chelation Therapy	43
1.12	Some Historical Connections	43
1.12.1	Charles Darwin	43
1.12.2	Karin Blixen aka Isak Dinesen	46

Is Arsenic an Aphrodisiac? The Sociochemistry of an Element

By William R. Cullen

© William R. Cullen 2008

1.12.3 Alexander Borodin, Professional Organic Chemist and Amateur Composer	46
References	47

Chapter 2 Arsenic Where You Least Expect It

2.1 Animal Feed Additives	58
2.2 Heartworm	60
2.3 Pesticides and Herbicides	61
2.3.1 Lead and Calcium Arsenates	61
2.4 Arsenic Trioxide	63
2.4.1 The Black Death	63
2.5 Wood Preservation	67
2.5.1 Chromated Copper Arsenate (CCA)	67
2.5.2 Disposal of Treated Wood	72
2.5.3 Alternatives to CCA	74
2.6 Monomethylarsonic Acid and Dimethylarsinic Acid	75
2.6.1 Use in the USA	75
2.6.2 Canada	76
2.7 OBPA	78
2.8 Arsenic in Other Products and Processes	78
2.8.1 Ironite	78
2.8.2 Gallium Arsenide	79
2.8.3 Glass Making	80
2.8.4 Embalming	81
2.8.5 Taxidermy	85
2.8.6 Pigments	87
2.9 Some Historical Connections	88
2.9.1 Clare Boothe Luce	88
2.9.2 The Peale Family	89
2.9.3 King George III	90
References	92

Chapter 3 Arsine, Scheele's Green, Gosio Gas, and Beer

3.1 Arsine	99
3.2 Scheele's Green	103
3.3 Arsenical Wallpaper	105
3.3.1 Coal Tar Dyes and the Decline of Arsenical Colours	106
3.4 Medical Problems	107
3.5 Wallpaper Dust or Gas?	109
3.6 Gosio Gas	110
3.7 The Regulation of Arsenic, the "Verdant Assassin"	112
3.8 Other Assassins	113

3.9	Frederick Challenger	115
3.10	The Toxicity of Gosio Gas	118
3.11	Sick-Building Syndrome?	120
3.12	The Manchester Beer Incident	120
3.13	An Historical Connection. William Morris	124
	References	127

Chapter 4 Arsenophobia: A Connection between the Deaths of Infants and Napoleon I

4.1	Sudden Infant Death Syndrome	130
4.2	The Toxic-Gas Hypothesis	131
4.2.1	The Reaction	133
4.2.2	The Turner Commission	134
4.2.3	The Back-to-Sleep Campaign	135
4.3	The Limerick Report	137
4.3.1	Antimony Biomethylation	138
4.3.2	Report Summary	139
4.4	Dr. T. J. Sprott	140
4.4.1	Sheep Skins	141
4.5	Other Proponents of the Toxic-Gas Hypothesis	143
4.6	Toxicity and Related Considerations	144
4.7	The Death of Napoleon I of France	145
4.7.1	Was it the Arsenic in the Wallpaper?	145
4.7.2	The Autopsy	146
4.7.3	Arsenic Poisoning?	147
4.7.4	The “Real” Cause of Napoleon’s Death	151
4.7.5	Who Did It?	152
4.8	Some Analytical and Chemical Problems	152
4.8.1	The Preservation of the Corpse	152
4.8.2	The Lethal Phase	153
4.8.3	The Hair Analysis	153
4.9	The Overall Picture	155
4.9.1	Sources of Arsenic	157
4.9.2	Wine and Water	157
4.9.3	Self-medication	158
4.9.4	Arsenical Smoke and Preservatives	158
4.9.5	Arsenical Straws	160
4.10	Medical Evidence	160
	References	161

Chapter 5 Arsenic and Crime: The Law of Intended Consequences

5.1	Introduction	166
5.2	Ancient Times	167

5.3	European Excess: The Age of Arsenic	167
5.3.1	Italy of the Borgias and the Medicis	168
5.3.2	France: The Poisons Affair	170
5.4	Forensic Science	171
5.4.1	Mary Blandy	172
5.4.2	James Marsh	173
5.4.3	Marie Lafarge	174
5.4.4	The Arsenic Act of 1851	176
5.4.5	Madeleine Smith	178
5.4.6	Thomas Smethurst	181
5.4.7	Florence Maybrick	183
5.4.8	Herbert Armstrong	185
5.4.9	Marie Besnard	187
5.5	Public Perceptions	188
5.5.1	Arsenic and Old Lace	189
5.5.2	Crime Fiction	190
5.5.3	Portrait of a Poisoner	191
5.6	Some Serial Killers	192
5.6.1	Mary Ann Cotton, Britain's First Serial Killer	192
5.6.2	The Black Widows of Liverpool	193
5.6.3	Vera Renczi	194
5.6.4	Madame Popova	194
5.6.5	Johann Hoch	195
5.6.6	The Arsenic Gang	195
5.6.7	The Grandmothers of Nagyrev	195
5.6.8	Dr. Michael Swango	196
5.6.9	Donald Harvey	197
5.7	Delivery Systems	197
5.7.1	Food and Drink	197
5.7.2	The Poisoned Shirt	198
5.7.3	Application via a Prophylactic	198
5.7.4	The Poisoned Maiden	198
5.7.5	The Poisoned Ring	199
5.7.6	The Poisoned Candle	199
5.8	Public Arsenic Attacks	199
5.8.1	Japanese Curry	199
5.8.2	Campus Coffee	200
5.8.3	Church Picnic	201
5.9	Two Ongoing Cases	202
5.9.1	A Political Poisoning	202
5.9.2	Cynthia Sommer	203
5.10	Bezoars, Unicorns and Food Tasters	205
5.11	Some Historical Connections	207
5.11.1	Zachary Taylor	207
5.11.2	Wolfgang Amadeus Mozart	208

5.11.3 Pyotr Ilyich Tchaikovsky	209
References	210

Chapter 6 Arsenic at War: Mass Murder

6.1 Introduction	215
6.2 The First Chemical Weapons Conventions	217
6.3 World War I: The Gas War	217
6.3.1 Mustard Gas	221
6.3.2 Blue Cross	223
6.3.3 Arsenical Agents: The Second Generation	224
6.3.4 Tactics of Chemical Warfare	225
6.4 The US Enters the Fray	226
6.4.1 Lewisite	227
6.4.2 Phenarsazine Chloride	228
6.5 Arsenical Chemical-Warfare Agents	232
6.6 Casualties of the Chemical War	233
6.6.1 The Combatants	233
6.6.2 Civilian Casualties	234
6.7 The Aftermath	234
6.7.1 The Humane War?	234
6.7.2 Public Reaction	235
6.8 Living with Chemical Weapons	239
6.8.1 The Geneva Convention	239
6.8.2 The German Reaction	240
6.8.3 Spain in Morocco	240
6.8.4 Italy in Ethiopia (Abyssinia)	241
6.8.5 Japan in China	242
6.9 WWII – The Gas War That Never Happened	244
6.9.1 The Buildup in Europe	244
6.9.2 Russia	245
6.9.3 The United States	245
6.9.4 Canada	246
6.9.5 The European Experience	250
6.9.6 The War in the Pacific	251
6.10 Human Guinea Pigs	252
6.10.1 The Allies	252
6.10.2 Japan and Germany	254
6.10.3 The Nuremberg Code of 1947 and its Aftermath	254
6.11 The Vietnam War	257
6.11.1 Agent Blue	257
6.11.2 Adamsite and Other Tear Gases	259
6.11.3 Health Effects	259
6.11.4 The Public Reaction	260
6.12 The Chemical Weapons Convention	261

6.13	The Cleanup	263
6.13.1	The Early Years	263
6.13.2	Post-WWII	264
6.13.3	Japan	266
6.13.4	Domestic Ocean Dumping	266
6.14	Disposal of Stockpiles	267
6.14.1	Russia	267
6.14.2	United States	268
6.15	Some Special Problems	270
6.15.1	Munster, Germany	270
6.15.2	Spring Valley, US	271
6.15.3	Bowes Moor, UK	272
6.15.4	China	272
6.15.5	Albania	273
6.15.6	Other Recent Deployments of Chemical Weapons	274
6.16	Conclusions	275
	References	277

Chapter 7 Arsenic and the Environment

7.1	Introduction	287
7.1.1	Arsenic in the Atmosphere	288
7.1.2	Arsenic in the Pedosphere	288
7.1.3	Arsenic in the Hydrosphere	288
7.2	Arsenic in the Biosphere	289
7.2.1	Arsenic in Seafood	289
7.2.2	Analysis of Arsenic Species (Speciation) in Living Organisms	290
7.2.3	Distribution of Arsenic Species in the Living Environment	294
7.2.4	Where do Arsenosugars and Arsenobetaine Come From?	296
7.2.5	Arsenic Accumulators and Hyperaccumulators	299
7.3	Arsenic in Our Food and Water	300
7.3.1	Essentiality	301
7.3.2	Arsenic Market Baskets	302
7.3.3	The Effect of Cooking	304
7.3.4	More on Rice	304
7.3.5	Hijiki and Other Algal Products	305
7.3.6	Bottled Water	308
7.3.7	Metabolites	310
7.4	Bioavailability and Bioaccessibility	310
7.4.1	Sequential Selective Extraction (SSE)	312
7.4.2	Gastrointestinal Models	312

7.5	Arsenic in the Anthrosphere	313
7.5.1	Gold Prospecting	314
7.6	Arsenic Trioxide and the Giant Mine, Yellowknife NT, Canada	315
7.6.1	Giant Mine: An Underground Cleanup?	317
7.6.2	Giant Mine: Surface Cleanup	318
7.7	American Smelting and Refining Company. Asarco	319
7.7.1	The Everett and Tacoma Smelters	319
7.7.2	The Globe Smelter: Some Unexpected Relief	321
7.8	A Transboundary Dispute: Teck Cominco vs. US EPA	321
7.9	More Woes	322
7.9.1	Some Other Surfaces Affected by Mining	322
7.9.2	Nickel Arsenide	323
7.10	Arsenic in Energy Sources	324
7.10.1	Coal	324
7.10.2	Arsenical Peppers	326
7.10.3	The Oil Sands of Alberta	327
7.10.4	The Sydney Tar Ponds: Arsenic as an Environmental Hammer	328
7.10.5	Cleaning Up	329
7.10.6	Monitored Natural Attenuation	331
7.11	Microbes and Arsenic	332
7.11.1	More – but very Small – Arsenic Eaters	333
	References	339

Chapter 8 Accidental Exposure to Arsenic: The Law of Unintended Consequences

8.1	Introduction	349
8.2	West Bengal and Bangladesh: The Devil's Water	350
8.2.1	The Green Revolution	350
8.2.2	Bangladesh	351
8.2.3	The Affected	354
8.2.4	Where does the Bangladesh Arsenic Come From?	355
8.3	Professor Dipankar Chakraborti	358
8.3.1	Field Testing Kits	360
8.4	Arsenic Mitigation in Bangladesh	362
8.4.1	Dhaka, Bangladesh, January 2002	362
8.4.2	Arsenic-Mitigation Technologies	364
8.4.3	Verification of Mitigation Technologies	365
8.4.4	The Grainger Challenge Prize	367
8.4.5	Nanoparticles	369
8.4.6	Other Arsenic-Mitigation Methods	369

8.5	Where Are We Now?	370
8.5.1	Treatment Options for the Afflicted	370
8.5.2	Arsenic Mitigation	371
8.6	Taiwan	373
8.6.1	Southwestern Taiwan	373
8.6.2	Northern Taiwan	373
8.7	Vietnam and Elsewhere in the East	374
8.7.1	Vietnam	374
8.7.2	Nepal	374
8.7.3	China and Japan	374
8.8	South America	375
8.8.1	Argentina	375
8.8.2	Chile	375
8.9	Africa	376
8.10	Europe	378
8.11	North America	379
8.11.1	Mexico	379
8.11.2	The US Standard for Drinking Water	379
8.11.3	Setting the US MCL	381
8.11.4	Cost/Benefit Analysis	383
8.11.5	The MCL Revisited	385
8.11.6	Fallon, Churchill County, Nevada	385
8.12	Other Small Systems	387
8.13	The Canadian Maximum Acceptable Concentration (MAC)	387
8.14	The Opportunists Knock	387
8.15	Epilogue	388
	References	389
	Subject Index	398