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Cyanide, Mining, and the Environment

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I. INTRODUCTION

North America's largest gold and copper mine could be located in the hills above Bristol Bay in Alaska—home to the largest sockeye salmon fishery in the world.[1] But the prospect of actually developing it is in doubt, amid fears about the threat posed to the environment by the mine's possible reliance on cyanide as a leachate to remove the valuable minerals.[2] One of the largest deposits of gold in Montana, the Seven-Up Pete McDonald Project, remains untouched because, by popular initiative, Montana citizens voted to prohibit the use of cyanide in gold mining opera-

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1. The proposed Pebble Mine would lie in the Bristol Bay watershed in southwestern Alaska. *See* Kim Murphy, *Pebble Mine Could Devastate Alaska Rivers*, L.A. TIMES, May 18, 2012, http://articles.latimes.com/2012/may/18/nation/la-na-nn-pebble-mine-epa-20120518.

2. *See* Beck Bohrer, *Mining Could Affect Quality of Water, Fish*, U-T SAN DIEGO, May 18, 2012, http://www.utsandiego.com/news/2012/may/18/epa-mining-could-affect-quality-of-water-fish/; GROUND TRUTH TREKKING, PEBBLE MINE (COPPER/GOLD PROSPECT), http://www.groundtruthtrekking.org/Issues/MetalsMining/pebble-mine-gold-copper-prospect-alaska.html (last modified Mar. 14, 2013).

tions.[3] These voters feared that cyanide would be used by the mine and were concerned about its effect on the nearby rivers.[4] The fear of cyanide in mining is not limited to the United States—it is international. The European Parliament has called for a complete ban on the use of cyanide mining technologies in the European Union because a ban "is the only way to protect [] water resources and ecosystems against cyanide pollution from mining activities."[5] Several EU nation states have already completely banned cyanide in mining.[6]

Concern, if not outright fear, about the potential environmental threat of cyanide in mining has either halted gold and copper mining operations in America and elsewhere around the world, or caused such operations to be delayed and vigorously opposed.[7] The fear of cyanide itself inflates the public's perceived risk, sometimes resulting in cyanide bans that eliminate opportunities like the Seven-Up Pete McDonald Project.[8] The serious-

3. Citizen's Initiative I-137 was upheld against an attack on its constitutionality. *See* Seven Up Pete Venture v. Montana, 114 P.3d 1009 (Mont. 2005).

4. Dorothy Kosich, *Mountain States to Resurrect McDonald Gold Project Takings Case*, MINEWEB (July 23, 2008), http://www.mineweb.com/mineweb/view/mineweb/en/page43/page34?oid=57433&sn=Detail ("Montana voters twice voted to ban the use of cyanide in recovery of gold in new mining projects."); *see also* Pratap Chatterjee, *Montana Voters Nix Use of Cyanide Poison in Mining,* THE PROGRESS REP., http://www.progress.org/mining04.htm (last visited Jan. 8, 2013).

5. *See* Don Smith, *European Parliament Calls for "Complete Ban on Use of Cyanide Mining Technologies" in European Union and for EU States to Oppose Cyanide Use Elsewhere*, UNIV. DENVER STERM COLL. L. (June 25, 2010, 6:09 AM), http://www.enrlgp.blogspot.com/2010/06/european-parliament-calls-for-complete.html.

6. Cyanide is banned in the Czech Republic, Hungary, and Germany. *See* Resolution on General Ban on the Use of Cyanide Mining Technologies in the European Union, EUR. PARL. DOC. P7 TA 0145 (2010) [hereinafter Resolution on Ban on Use of Cyanide], *available at* http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//TEXT+TA+P7-TA-2010-0145+0+DOC+XML+V0//EN.

7. *See Seven Up Pete Venture*, 114 P.3d at 1009; *see also Our View: EPA Is Doing Its Job*, ANCHORAGE DAILY NEWS, May 3, 2012, http://www.adn.com/2012/05/03/2451323/our-view-epa-is-doing-its-job.html ("Native groups and others in the [Alaska] region have asked the EPA to kill [the Pebble Mine] off.").

8. *See infra* Part IV.B. Montana citizens who helped ban cyanide compared the use of cyanide to one "long lethal injection" to those in the surrounding communities*; see Mining Seven-Up Pete: Cyanide Heap-Leach Gold Mine in Montana* (High Plains Films 1995), *available at* http://www.highplainsfilms.org/hpf/films/mining_seven_up_pete/buy-film/.

ness of these concerns means that if the modern miner does not debunk fears of cyanide before a mine is proposed, significant opposition to a proposed gold mine will likely be mounted. Moreover, since virtually all modern gold mines use cyanide, and since the price of gold has been fluctuating between $1,880 and $1,400/ounce,[9] a decision to halt a mine based on fear of cyanide use can obviously have significant economic repercussions, both for the mine investors and the surrounding community which may depend on the mine for employment.

Cyanide is certainly a chemical that is toxic and lethal to humans if ingested.[10] This is likely why its use by the mining industry often instills fear, anger, and opposition by both the communities near the mine and the environmental community.[11] Neighbors of mines and environmental organizations often fervently believe that mining operations using cyanide pose a grave threat to the natural environment. But, what is the truth, or ecological reality, of cyanide-dependent mining operations and environmental quality? Does use of cyanide in a gold mine inevitably, or even usually, result in damage to ecosystems or wildlife? How often does cyanide escape from mine sites, and if there is a cyanide release, do human health problems, environmental damage, and death of wildlife always follow?

If one reviews the use of cyanide by mines, especially gold and copper mines, what is revealed is that environmental incidents involving cyanide releases are extremely rare.[12] And when they do occur, their negative effects on natural systems and living organisms are often temporary.[13] If one then takes a careful look at the chemistry, science, and management of cyanide, one dis-

9. GOLDPRICE, www.goldprice.org (last visited May 14, 2013); Rujun Shen, *Precious – Gold Inches Up As More Cbank Action Eyed*, REUTERS (Oct. 2, 2012), http://af.reuters.com/article/commoditiesNews/idAFL3E8L21KA20121002.

10. *See Environmental and Health Effects of Cyanide*, INT'L CYANIDE MGMT. CODE, http://www.cyanidecode.org/cyanide_environmental.php (last visited Mar. 12, 2013).

11. *See* ROBERT MORAN, MINERAL POL'Y CTR., CYANIDE UNCERTAINTIES: OBSERVATIONS ON THE CHEMISTRY, TOXICITY, AND ANALYSIS OF CYANIDE IN MINING-RELATED WATERS (1998) [hereinafter CYANIDE UNCERTAINTIES], *available at* http://www.portaec.net/library/pollution/observations_on_the_chemistry.html.

12. *See Cyanide Chemistry*, INT'L CYANIDE MGMT. INST., http://www.cyanidecode.org/cyanide_chemistry.php (last visited Mar. 19, 2013).

13. *See infra* Part IV.A.

covers a two-pronged explanation for cyanide's relatively safe and uneventful environmental record. First, virtually all companies in the mining business that use cyanide have in place extensive systems to both prevent cyanide spills, and to mitigate environmental damage in the rare case when a spill occurs.[14] Second, cyanide itself is not inherently toxic to nature; indeed, it tends to degrade quickly, usually producing negligible environmental consequences.[15]

If the real environmental risks of cyanide in mining are comparatively low, why then is the perceived risk so alarmingly high? This perceived risk of environmental harm is so high that many jurisdictions in America and other countries either ban cyanide use entirely, or impose stringent regulatory conditions on its use.[16] Indeed, sometimes these regulations are so strict that one could argue they are an example of "over-regulation." This Article seeks to understand and explain this enormous gap between the scientific, chemical, ecological, and historical *reality* of cyanide-dependent mining operations, and the exaggerated, *perceived threat* of cyanide to overall environmental quality. The Article is not intended to serve as an advocacy polemic for the cyanide-using mining industry. Rather, its objective is two-fold: (1) It seeks to expose the scientific and environmental reality of cyanide use in mining operations; and (2) It will try to draw from the case of mining-and-cyanide use some larger lessons about regulatory behavior, and the downside of over-regulation when confronting the phenomenon of risk amplification.

Part II considers why cyanide is so ubiquitous in hard rock mining operations in America and in other countries, and why

14. *See infra* Part III.

15. *See* STEWART NEEDHAM, ENV'T AUSTL., CYANIDE MANAGEMENT 1 (2003), *available at* http://www.ret.gov.au/resources/Documents/LPSDP/BPEMCyanide.pdf ("[Cyanide] also oxidizes and degrades when exposed to air or other oxidants. While it is a deadly poison when ingested, inhaled or contacted in a sufficiently high dose, it does not accumulate in the food chain, and will generally not give rise to chronic health or environmental problems when present in low concentrations."); *see also infra* Parts IV-V.

16. *See* Resolution on Ban on Use of Cyanide, *supra* note 6; *see generally* Jan G. Laitos, *The Current Status of Cyanide Regulations*, ENG'G & MINING J., http://www.e-mj.com/index.php/features/1656-the-current-status-of-cyanide-regulations (last visited Mar. 19, 2013) [hereinafter Laitos, *Current Status of Cyanide Regulations*].

there is no effective substitute for it as a substance to leach out gold, copper, and other valuable hard rock minerals. Part III is an examination of the scientific and ecological reality of cyanide spills in nature. Part III reveals how, as a matter of science and chemistry, cyanide is usually, and counter-intuitively, non-toxic to environmental goods and wildlife. Part IV summarizes the true extent of the mining accidents and incidents that have released cyanide into the natural environment, and the very "human" reasons for these spills. Part IV also points out why, despite the fact that cyanide spills are preventable, and despite cyanide's undeserved reputation as a killer-of-environmental goods, there have been flat bans and harsh regulatory limitations on its use.

Since the scientific reality of cyanide's threat to the environment is nowhere near as grave as the regulatory response to it suggests, Part V suggests that there must be another reality that is driving the public's fear of cyanide. This other reality that must be taken into account is the "amplification of risk" that occurs when a substance like cyanide comes laden with so many pejorative associations.[17] The phenomenon of risk amplification is so pronounced in the case of cyanide that scientific and ecological reality is often ignored in favor of easy-to-understand, easy-to-impose, and politically expedient prohibitions that are to protect the surrounding environment and its fearful neighbors from the *perceived* of risk.

Part VI is a proposed qualitative risk assessment that evaluates the likelihood, in light of the findings articulated in Parts III and IV, that cyanide will create an adverse environmental impact when it is used in mines. Such a risk assessment considers both the *probability* of a cyanide spill occurring that might cause harm to environmental assets (Part IV), and the *risk* of ecological loss when using cyanide (Part III). This risk assessment reflects the reality of risk amplification by adding as a major *uncertainty* factor the powerful perception that cyanide poses a frightening threat to natural goods when it is used by mining operations (Part V). This enhanced perception of risk is so strong that the

17. *See generally* PAUL SLOVIC, THE FEELING OF RISK, NEW PERSPECTIVES ON RISK PERCEPTION (2010); Cass R. Sunstein, *The Arithmetic of Arsenic*, 90 GEO. L.J. 2255 (2002).

final component of a qualitative risk assessment—*mitigation*—needs to be reinterpreted so that it is not limited to mine-site mitigation measures that can be employed to reduce the potential harm that cyanide could pose to the environment. Another mitigation measure that should be added by those advancing the interests of cyanide use in mines is the need to address, and actively refute, the widely-held public perception that no amount of mitigation can prevent environmental damage when using something as inherently deadly and toxic as cyanide.

II. CYANIDE AND THE HARD ROCK MINING INDUSTRY

A. Why Does the Hardrock Mining Industry Depend upon Cyanide?

"The mining industry primarily uses cyanide to extract silver and gold from ores, but cyanide is also used in low concentrations as a flotation reagent for the recovery of base metals such as copper, lead and zinc."[18] The first cyanide mineral leaching processes were introduced in New Zealand over a century ago.[19] However, it was not until the 1970's that major U.S. mine operations began to replace traditional milling operations with cyanide leaching.[20] The primary advantage of cyanide was and is that, as a result of technical advances in mineral leaching techniques, mine operators were finally able to efficiently and profitably remove gold and other precious metals from extremely low-grade ore deposits.[21] Prior to cyanide use, gold could be profitably removed only if it was in a vein, lode, or high yield placer deposit.[22]

18. MICHAEL BOTZ, OVERVIEW OF CYANIDE TREATMENT METHODS 1 (1999), *available at* http://www.infomine.com/publications/docs/Botz1999.pdf.

19. *See* MARK J. LOGSDON ET AL., INT'L COUNCIL ON METALS AND THE ENV'T, THE MANAGEMENT OF CYANIDE IN GOLD EXTRACTION (1999).

20. *See* MIN. POL'Y CTR., CYANIDE LEACH MINING PACKET 2 (2000) [hereinafter CYANIDE LEACH MINING PACKET], *available at* http://www.earthworksaction.org/files/publications/Cyanide_Leach_Packet.pdf.

21. *Id.*

22. *Id.*; *see also* E.H. WELLS & T. P. WOOTTON, N.M. SCH. MINES, GOLD MINING AND GOLD DEPOSITS IN NEW MEXICO 3 (1932), *available at* http://geoinfo.nmt.edu/publications/circulars/downloads/5/Circular%2005.pdf.

After the adoption of cyanide leaching, gold could be extracted for a profit where the amount in the host rock was quite small compared to the quantity of non-mineral grade rock surrounding the gold.[23]

Cyanide heap leaching became so efficient at precipitating gold out of the ore that areas which had previously been unsuitable for precious metals mining were now able to be mined, albeit at the cost of having to remove and crush enormous amounts of host rock into large "heaps."[24] Cyanide solutions could then be sprayed on these heaps to separate and collect the gold bearing solution.[25] This release of cyanide gave rise to the possibility of accidental releases into the natural environment, creating the perceived threat of ecosystem poisoning. Nonetheless, by the 21st century, over 90% of gold extracted worldwide is the result of cyanide leaching techniques.[26]

Prior to the introduction of cyanide leaching operations, most low-grade ore deposits could not be profitably removed using traditional placer or lode mining techniques; to that end, the low capital costs associated with cyanide heap leaching have made profitability on low-grade ores a reality.[27] By utilizing cyanide mineral leaching techniques in large-tonnage mine projects, operators were able to extract small, sometimes microscopic flecks of gold and other precious minerals from low-grade ore with 90% to 95% efficiency.[28] As a result of the efficiency of heap leaching, mountains full low-grade ore have been transformed into profitable mineral extraction operations.

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23. *See* CYANIDE LEACH MINING PACKET, *supra* note 20.

24. See *id.*

25. *See id.*

26. *See* T.I. Mudder & M.M. Botz, *Cyanide and Society: A Critical Review*, 4 EUR. J. MIN. PROCESSING & ENVTL. PROTECTION 62 (2004).

27. *See* Harold Hough, *Heap Leaching Technology-Greener and Cheaper,* MINERS NEWS (Jan. 2010), http://www.minersnews.com/Dec09Jan10/HeapLeach.html; *see also* Bruce Most, *Gold Rush!*, 165 POPULAR MECHANICS 62, 64 (Mar. 1998).

28. *See Recovery of Gold and Silver by Cyanidation*, GOLD & SILVER METALLURGY, http://www.goldandsilvermetallurgy.com/gold-recovery/ cyanidation-process/recovery-of-gold-and-silver-by-cyanidation (last visited Mar. 21, 2013).

In the case of gold, global adoption of cyanide leaching operations can be explained by the prevalence of low-grade gold ore deposits. By the 21st century, virtually all the lodes and veins and easy to access placer deposits had been discovered and removed worldwide, leaving mostly low-grade ore deposits.[29] What remains are hills and mountains where the gold is barely present, and then only in microscopic quantities.[30] Thus, to be able to profitably extract gold from such deposits, virtually every fraction of an ounce of the gold that exists in the host deposit must be removed from the surrounding rock. The unique chemical properties of cyanide permit it to quickly and effortlessly dissolve, or "leach out," gold and other metals from non-valuable host rock.[31] Cyanide has unlocked those specks of precious minerals, permitting development of thousands of pounds of gold and silver in the midst of millions and millions of tons of otherwise non-valuable rock.[32] Cyanide is a truly magical substance that may facilitate the efficient and economic extraction of gold and other precious minerals from the world's low-grade ore deposits.[33] Unfortunately, this incredible substance is also a toxic poison.[34]

B. Alternatives to Cyanide?

Because cyanide is a poison, with the capacity to damage the natural environment surrounding a mine using it, a logical inquiry is whether a less harmful substance could substitute and yield the same economic results. As regulations have stiffened surrounding the use of cyanide,[35] making its use more expensive, the attractiveness of a cyanide alternative has become more pronounced. There have also been calls for increased and aggressive

29. *See generally Ranking World Gold Mines & Deposit*, RES. INV., http://www.resourceinvestor.com/2012/07/27/ranking-world-gold-mines-deposits (last visited Mar. 21, 2013).

30. *Id.*

31. *Cyanide Leaching*, SGS MINING, http://www.sgs.com/en/Mining/Metallurgy-and-Process-Design/Cyanidation-Technologies/Cyanide-Leaching.aspx (last visited Mar. 28, 2013).

32. *See* CYANIDE LEACH MINING PACKET, *supra* note 20.

33. *Id.*

34. *Id.*

35. *See generally* Laitos, *Current Status of Cyanide Regulations*, *supra* note 16.

legal oversight, and in some instances, complete bans.[36] This mounting criticism of cyanide leaching has "fueled considerable research into more environmentally benign alternatives."[37]

In devising a suitable substitute for cyanide in mineral processing, the primary challenge lies in developing an equally efficient, cost effective, and easily degradable leaching solution, which is not a persistent environmental toxin.[38] In other words, like cyanide, a substitute must be able to select the gold from the hardrock, and then be able to inexpensively separate and leach it out for extraction and processing. In light of these attributes of cyanide, alternative methods should be:

1. inexpensive and recyclable
2. selective
3. non-toxic
4. compatible with downstream recovery processes.[39]

Even after almost a century's worth of research investigating methods of mineral removal, cyanide remains the predominate method of gold extraction worldwide.[40] It has the distinct, and unique ability to separate out valuable minerals from surrounding rock at a relatively low cost.[41] Fortunately in terms of the natural environment's sake, most gold milling and heap leaching processes utilize cyanide at low concentrations, which means it quickly degrades into other non-toxic substances.[42] Cyanide's ability to rapidly degrade into a non-toxic form is due to the fact

36. For example, in 1998, the citizens of Montana passed citizen ballot Initiative 137 (I-137) and voted to ban the use of cyanide in the mining industry. *See* MT. FISH WILDLIFE & PARKS, RESHAPING OF THE POLITICAL ENVIRONMENT IN MONTANA: IMPLICATIONS FOR MONTANA FISH, WILDLIFE AND PARKS (2004), *available at* http://fwp.mt.gov/doingBusiness/reference/montanaChallenge/reports/political.html; MONT. CODE ANN. § 82-4-390 (1998); *see* Rob Krueger, *Relocating Regulation in Montana's Gold Mining Industry*, 34 ENV'T & PLAN. 867 (2002); *see generally* Laitos, *Current Status of Cyanide Regulations, supra* note 16.

37. Gavin Hilson & A.J. Monhemius, *Alternatives to Cyanide in the Gold Mining Industry: What Prospects for the Future?*, 14 J. CLEANER PROD. 1158 (2005).

38. *Id.*

39. *Id.*

40. *See* Mudder & Botz *supra* note 26, at 62.

41. *See* NEEDHAM, *supra* note 15, at 5.

42. *See* CYANIDE LEACH MINING PACKET, *supra* note 20.

that, as a chemical compound, it is not necessarily poisonous; it is surprisingly ubiquitous in nature, typically in a non-toxic state.[43] Indeed, it is naturally produced by many micro-organisms, as well as over 2,500 species of plant.[44] It is readily transformed by natural, physical, chemical, and biological processes into non-toxic forms that are already in the environment.[45] However, cyanide can also bond with other chemicals, and when it does, it may create very toxic and lethal compounds, capable of producing adverse health effects and environmental harm.[46]

The primary challenge in developing an effective alternative to cyanide rests in: (1) ensuring the particular chemical and metallurgical process selected for the extraction of gold matches the characteristics of the ore; (2) the alternative substance is a degradable leach reagent; and (3) it is not a persistent environmental toxin.[47] Despite significant research into the development of plausible alternatives—driven mainly by economics—the list of substitutes is limited.[48] Most are effective with respect only to refractory ores—those which otherwise resist chemical leaching processes, making it difficult to separate the valuable minerals away from ore.[49] Such ores are not the target of most mining operations, which are largely focused on gold and other valuable minerals now capable of extraction through simple cyanide leaching processes.[50]

There are a number of possible alternatives to cyanide, and the most promising are the non-cyanide lixiviants—thiourea, thiosulphate, thiocyanate.[51] Other possibilities include coal-oil agglomeration, halides, the Haber Gold Process (HGP), and the

43. *See generally* Hilson & Monhemius, *supra* note 37.
44. *Id.*
45. *Id.*
46. *Id.*
47. *Id.*
48. *See* NEEDHAM, *supra* note 15, at 16.
49. *See generally* JOHN C. YANNOPOULOS, THE EXTRACTIVE METALURGY OF GOLD (1991).
50. *Id.*
51. *See* Hilson & Monhemius, *supra* note 37.

"YES-Process" for gold and silver extraction.[52] Each has its own set of limitations and downsides when compared to cyanide.

Thiourea Leaching of Gold. Thiourea, a gold leaching agent, is a possible alternative because it leaches gold more rapidly than cyanide, and is less toxic.[53] It can be used on refractory ores otherwise resistant to cyanide, and in heap and in situ leaching processes.[54] Commercial adoption of thiourea is primarily hindered by five factors:

1. Thirourea is far more expensive that cyanide because of the quantity of solution required in the leaching process;
2. gold processing consumes high amounts of thiourea solution;
3. it has limited recyclability;
4. the detoxification costs are typically high; and
5. the gold recovery steps require further development as current process parameters for mineral extraction are difficult to control.[55]

Thiosulphate Leaching. Thiosulphate, a chemical commonly used in photography and the pharmaceuticals industries, has received serious consideration as a potential substitute for cyanide because it generally causes fewer adverse environmental impacts.[56] Some studies have reported gold recovery rates exceeding 90% when incorporating various pre-treatment strategies.[57] In commercial practice, Newmont Gold and Consolidated Empire

52. *See* SZILVIA SZILÁGYI, JUSTICE & ENV'T, BANNING CYANIDE FROM MINING IN THE EUROPEAN UNION 6 (2011), *available at* http://www.justiceandenvironment.org/_files/file/2011%20cyanide%20analysis.pdf.

53. *See* Jana Ficeriová et al., *Leaching of Gold and Silver from Crushed Au-Ag Wastes*, 2 OPEN CHEM. ENG'G J. 6 (2008), *available at* http://www.benthamscience.com/open/tocengj/articles/V002/6TOCENGJ.pdf.

54. *See* Hilson & Monhemius, *supra* note 37, at 1161-62; *see also* C. Swaminathan et al., *Reagent Trends in the Gold Extraction Industry*, 6 MIN. ENG'G 1, 1-16 (1993).

55. *See* Hilson & Monhemius, *supra* note 37, at 1162.

56. As compared to cyanide, there are fewer environmental concerns because thiosulphate leaching poses fewer pollution concerns and exhibits less interference from foreign cations, which are positively charged ions. *See* D. Feng & JSJ Van Deventer, *Leaching Behaviour of Sulphides in Ammoniacal Thiosulphate Systems*, 63 HYDROMETALLURGY 189, 189-200 (2002).

57. *See* Hilson & Monhemius, *supra* note 37.

Gold Inc. have successfully used thiosulphate in heap leaching of gold ore.[58]

The main problem with thiosulphate leaching is the high rate of consumption of the solution during extraction.[59] Additionally, thiosulphate leaching rates are slow, although process speed can be improved with the addition of ammonia, and by using copper as an oxidant.[60] However, the high rate of chemical consumption renders most thiosulphate leaching operations economically inefficient overall, despite their potential environmental benefits.[61] These disadvantages prevent thiosulphate leaching from becoming a simple method of gold recovery.[62]

Thiocyanate. Although there is not yet a critical mass of thorough research about thiocynate, experiments have shown that leaching systems relying on it perform comparably to cyanide.[63] Thiocyanate has also been shown to be considerably more effective than thiourea and more stable than both thiosulphate and thiourea.[64] However, thiocyanate leaching is still in the experimental stage, and lacks adequate research before it can be considered as a viable alternative to cyanide.[65]

Coal-oil Agglomeration. The coal-oil-gold agglomeration (CGA) method has been recognized as a potential alternative to cyanide for both large-scale and small-scale (i.e, artisanal) operations.[66] However, because CGA is only effective at removing free gold particles (i.e., those within alluvial deposits and some pro-

58. *See id.*

59. *See* Feng & Van Deventer, *supra* note 56.

60. *See* Hilson & Monhemius, *supra* note 37.

61. *See id.*

62. *See* Ronald Eisler et al., *Sodium Cyanide Hazards to Fish and Other Wildlife from Gold Mining Operations, in* THE ENVIRONMENTAL IMPACTS OF MINING ACTIVITIES 55, 55-67 (Jose M. Azcue ed., 1999) [hereinafter *Sodium Cyanide Hazards to Fish*].

63. *See* A.J. Monhemius & S.P. Ball, *Leaching of Dominican Gold Ores in Iodide-Catalysed Thiocyannate Solutions*, 104 TRANSACTIONS OF THE INST. OF MINING & METALLURGY 117 (1995).

64. *See* Hilson & Monhemius, *supra* note 37, at 1163.

65. *See* O. Barbosa-Filho & A.J. Monhemius, *Leaching of Gold in Thiocyanate Solutions – Part 3: Rates and Mechanism of Gold Dissolution*, 103 TRANSACTIONS INST. MINING & METALLURGY 117, 117-25 (1994).

66. *See* Hilson & Monhemius, *supra* note 37, at 1164.

cess tailings), it has limited potential for large-scale operations.[67] Studies have shown CGA to be quicker, cleaner, and more effective at removing free gold particles than conventional gold processing techniques, including cyanidation.[68] Indeed, experimental work shows CGA to be a viable, and far less toxic, substitute to mercury amalgamation for small-scale (artisanal) miners.[69] CGA would produce fewer threats to the environment than the mercury amalgamation method currently preferred by artisanal miners, especially those operating outside of North-American countries.[70]

Halides.[71] Halide systems, which predate cyanidation, present another potential alternative to cyanide because they generally dissolve gold much faster than cyanide.[72] Halides that have been tested or used for gold extraction include chlorine, bromine, astatine, and iodine.[73] Bromine, in particular, offers some distinct advantages over other halides, including rapid extraction, non-toxicity, and adaptability to a wide range of pH values.[74] The bromine system has received increasing attention in the mining industry following a patent by the Great Lakes Corporation on its bromine-based gold leaching process.[75] However, while halide systems offer much quicker extraction rates than cyanide—if utilized under the right conditions—they are also generally unstable, technologically difficult to apply, and far more costly.[76]

67. *Id.*

68. *See generally* S.R. Bellamy et al., *Recovery of Fine Gold by Coal Gold Agglomeration*, GOLD FORUM ON TECH. & PRACTICES (1989).

69. *See* Hilson & Monhemius, *supra* note 37, at 1164.

70. *Id.*

71. Halides include fluorine, chlorine, bromine, iodine, and astatine. *See Halide*, ENCYC. BRITANNICA, http://www.britannica.com/EBchecked/topic/252495/halide (last visited Nov. 2, 2012).

72. *See* S.R. La Brooy et al., *Review of Gold Extraction from Ores*, 7 MINERALS ENG'G 1213 (1994).

73. Hilson & Monhemius, *supra* note 37, at 1164.

74. *See id.* at 1164-65.

75. *See* TAM TRAN ET AL., HALIDES AS AN ALTERNATIVE LIXIVIANT FOR GOLD PROCESSING – AN UPDATE (2001).

76. For example, halides are associated with high rates of reagent consumption, require expensive construction materials required to withstand sever acidic conditions, and are generally unstable and can combine with other elements to form extremely toxic compounds. *See* Hilson & Monhemius, *supra* note 37, at 1165.

The Haber Gold Process. Developed in the mid 1980's, the Haber Gold Process (HGP) appears to be cost effective, non-toxic, and able to avoid the release of heavy toxic metals from processed ores.[77] HGP extracts gold from ores by dissolving the gold into water and then recovering it.[78] The process can be applied to treat a variety of ore bodies, such as oxide and sulfide ores, and is effective at removing even micro fine gold particles.[79]

Acute Toxicity Testing performed by the California Department of Health Services showed the process to have an 85%-100% survival rate for aquatic organisms after the substances associated with HGP were introduced into an aquatic environment.[80] Preliminary and follow up testing, conducted by mine engineering groups, has shown that HGP results in more gold recovery during a shorter period of time than the cyanide leaching processes, with a cost comparable to, or less than, that associated with cyanide leaching processes. However, despite being very powerful (and capable of processing sulfide and oxide ores), HGP is not a universal lixiviate, and must be continually adjusted according to the unique properties of each ore body.[81] The consequence for mine operators is that while HGP may hold potential for future gold extraction, it may not yet be practical for many mineral deposits, and it has not yet been modified for operation at high-volume-mine operations.[82]

The "YES-process." The "YES-process," patented in 1995 by YES Technologies, is a cyanide-free, biocatalyzed leaching process,[83] which uses a bisulfide-leaching agent that is 200 times less toxic than cyanide.[84] The process is also a cost effective alternative to cyanide, with preliminary test results showing that

77. *See* Elizabeth McKinnon, *The Environmental Effects of Mining Waste Disposal at Lihir Gold Mine, Papua New Guinea*, 1 J. RURAL & REMOTE ENVTL. HEALTH 40, 49 (2002); *see also Haber Gold Process*, HABER, http://www.habercorp.com/index.php?id=75 (last visited Nov. 2, 2012).

78. McKinnon, *supra* note 77, at 49.

79. *See Haber Gold Process*, *supra* note 77.

80. *See* McKinnon, *supra* note 77, at 49.

81. *Id.*

82. *See Haber Gold Process*, *supra* note 77.

83. *See Cyanide-free Biocatalyzed Leaching of Gold and Silver Ore*, YES TECHS., http://yestech.com/tech/gold1.htm (last visited Nov. 2, 2012).

84. *See* SZILÁGYI, *supra* note 52, at 6.

the chemical reagent costs associated with the YES-process could be 80% lower than with cyanide operations.[85] Yes Technologies reports that the YES-process has achieved 75% gold extraction during two-stage leaching experiments.[86] Following Phase 1 studies, the company found no theoretical or practical reasons why an optimized YES process could not achieve an "efficiency and efficacy on par with cyanidation," with a concurrent 80% reduction in chemical reagent.[87] Unfortunately, the potential for the YES-process is speculative at best as the company is in need of additional funding for research and development to fine-tune critical steps in the metal extraction process.[88]

Until further research or technological breakthroughs makes one or more of the above alternatives to cyanide economically competitive, technologically feasible, and environmentally safe, cyanide leaching will remain the only practical method for large scale gold extraction processes; and because cyanide will likely be widely used to extract gold and other precious metals in America and throughout the world, any environmental incident involving cyanide spills will also likely be highly publicized due to its controversial public statute.[89] Indeed, much of the opposition to cyanide use in the mining industry seems to arise from a relatively small number of high visibility incidents, which were associated with environmental damage. However, as will be pointed out in Parts III and IV below, this harm was often not due to the inherent toxicity of cyanide, but instead was caused by either poor design or faulty operation of gold extraction processes.[90] Nonetheless, the fact that there have been examples of cyanide spills continues to drive the fear of cyanide use, and the opposition to it.

85. YES TECHS., *supra* note 83.
86. *Id.*
87. *Id.*
88. *See id*.
89. *See* dicta Parts I and II.A, *infra* Parts IV and V.B; Mudder & Botz, *supra* note 26, at 62.
90. *Infra* Part IV.

III. IS CYANIDE USE DANGEROUS TO THE ENVIRONMENT?

A scientific examination of cyanide reveals why it is so widely used in mining. The physical and chemical nature of cyanide makes it capable of being a leachate for valuable metals, especially with respect to gold.[91] A scientific look at cyanide also shows that the highly variable nature of mining operations will mean that the toxicity of cyanide will be difficult to predict,[92] which of course calls for extensive planning and mitigation design in order to prevent a catastrophic spill of cyanide. The science demonstrates, however, that with proper management, the toxic properties of cyanide can typically be mitigated,[93] not only for environmental and human safety, but also in the interest of the mining operation. In part this win-win nature of cyanide is due to the fact that if miners permit free cyanide (the most toxic form of cyanide)[94] to be formed during the operation, then the cyanide becomes less effective as a leachate. Thus, miners have a strong economic incentive to avoid cyanide that has the potential to harm the environment.

To evaluate the use and environmental safety of cyanide in mining, it is important to understand both (1) the physical and chemical properties that allow it to be such a good leachate capable of releasing gold and other valuable metals from rock, and (2) the variables which affect the toxicity of cyanide to living organisms, as well as cyanide's toxicity to the natural environment after exposure.[95] Fears of cyanide's toxicity have fueled calls for cyanide bans throughout American states and other countries,[96] so attention should focus first on the chemical and ecological real-

91. *See Gold Cyanidation*, GROUND TRUTH TREKKING, http://www.groundtruthtrekking.org/Issues/MetalsMining/GoldCyanidation.html (last visited Nov. 1, 2012).

92. *See* ROBERT E. MORAN, CYANIDE IN MINING: SOME OBSERVATIONS ON THE CHEMISTRY, TOXICITY, AND ANALYSIS OF MINING-RELATED WATERS 1, http://www.earthworksaction.org/files/publications/morancyanidepaper.pdf (last visited Nov. 1, 2012) [hereinafter CYANIDE IN MINING].

93. *See* LOGSDON ET AL., *supra* note 19, at 31.

94. *See id.* at 16.

95. *See id.* at iii.

96. *See Gold Cyanidation*, *supra* note 91.

ity of cyanide's relationship with the environment under varying conditions.

There is not just one kind of cyanide, which of course is perceived always to be a deadly poison. Cyanide forms compounds that are both highly toxic and relatively inert.[97] When inert, cyanide poses little danger to the environment.[98] When toxic, it is one of the most poisonous substances on this planet.[99] There are several chemical processes that lead to this high variation in toxicity. The critical variables that affect whether cyanide is stable or environmentally dangerous are, predominantly, water, pH, and complexation.[100] Water affects whether cyanide is diluted and how it is transported to the natural environment. A pH level tells chemists and regulators how acidic that water is, which in turn will have an effect on cyanide's toxicity.[101] Complexation is the combination of one or more elements (any chemical compound in which one molecule is linked to another by a coordinate bond);[102] for example gold combining with cyanide.[103]

Multiple chemical reactions may occur when cyanide is used in mining, such as volatilization (to evaporate or cause to evaporate),[104] oxidation (the addition of an oxygen molecule),[105] and precipitation (to cause a solid substance to be separated from a

97. *See* Bruce Coulombe, *The Truth About Cyanide Toxicity at MGP Sites*, THE GEI MGP REP. (2011), http://www.geiconsultants.com/stuff/contentmgr/files/0/550d7223743570d5672045cb584a7ad4/misc/nf_taylorville.pdf.

98. *Id.* at 2 ("Inert" is defined as "Not readily reactive with other elements; forming few or no chemical compounds." What this means is when a cyanide compound is inert, like a highly stable copper-cyanide compound, it does not readily convert or form into its highly toxic state which would adversely affect the environment. When a cyanide compound is strongly bonded to another element it is thus not biologically available or inert and unable to convert to toxic free cyanide, which can adversely affect living organisms and the environment.).

99. *See* LOGSDON ET AL., *supra* note 19, at 26.

100. *Cyanide Chemistry*, *supra* note 12.

101. *See* CYANIDE IN MINING, *supra* note 92, at 3.

102. *Complex*, THE FREE DICTIONARY, http://www.thefreedictionary.com/ complexation (last visited Jan. 12, 2013).

103. *See generally* CYANIDE IN MINING, *supra* note 92, at 3.

104. *Volatilization*, THE FREE DICTIONARY, http://www.thefreedictionary.com/volatization (last visited Jan. 12, 2013).

105. DEP'T HEALTH & AGING, PRIORITY EXISTING CHEMICAL ASSESSMENT REPORT NO. 31: SODIUM CYANIDE 109 (2010), *available at* http://www.nicnas.gov.au/Publications/CAR/PEC/PEC31/PEC_31_Full_Report_PDF.pdf.

solution).[106] Each of these chemical reactions led to changes in toxicity based on their ability to release toxic free cyanide.

The inherently variable nature of cyanide means that management schemes for ensuring the safety of cyanide in mining operations must be tailored to the specifics of the operation and its ecological setting. Cyanide rules for mining operations should reflect the nature of the operation, the surrounding environment, and the likelihood that a release of cyanide might occur. Mitigation measures also need to be in place in order to prevent the unintentional release of cyanide, and to minimize environmental impacts if such a release occurs.

A. The Chemical and Physical Properties of Sodium Cyanide

When used as a leachate in mining, the most commonly used form of cyanide is sodium cyanide.[107] The chemical compound sodium cyanide is considered a simple cyanide, one in which there is a single, negatively charged cyanide ion (CN-) combined with a single, positively charged sodium ion (NA+).[108] Simple cyanides, such as sodium cyanide, convert easily to hydrogen cyanide (HCN) and cyanide ion (-CN) in water, which is also known as "free cyanide."[109] The amount of free cyanide that is available directly relates to how toxic a solution is, so the more free cyanide present, the more toxic.[110] Conversely, complex cyanides do not readily degenerate, and therefore do not release toxic amounts of cyanide into the environment as easily.[111] Metal cyanide complexes are referred to as complex cyanides,[112] and are generally less toxic and more stable than simple cyanides while they are in

106. *Precipitation*, THE FREE DICTIONARY, http://www.thefreedictionary.com/precipitation (last visited Jan. 12, 2013).

107. *See* CYANIDE IN MINING, *supra* note 92, at 3.

108. *See id.*

109. *See id.*

110. *See Cyanide Chemistry*, *supra* note 12.

111. *See generally* C. Pohlandt et al., *A Critical Evaluation of Methods Applicable to the Determination of Cyanides*, J. S. AFR. INST. MINING & METALLURGY 11 (Jan. 1983).

112. DEP'T HEALTH & AGING, *supra* note 105.

that form.[113] Mining operations use simple cyanides, like sodium cyanide, in the leaching solution.[114] Simple cyanide is preferred because of its ability to dissolve and then combine with metals, such as gold to create complex cyanides.[115]

The pH of water is considered the most important factor controlling the toxicity of cyanide because it affects the amount of toxic free cyanide in a solution, as well as its efficiency as a leachate. At a pH of 7 (neutral), cyanide exists as free cyanide, and this more poisonous form of cyanide becomes more prevalent as the pH falls below 7 to acidic conditions. While lower pH releases cyanide to free cyanide form, slightly higher or basic pH increases cyanide's ability to leach gold.[116] As a result of this important role of pH, mining operations typically try to maintain the pH of the cyanide solution at a level between 9.5 and 11, where 10.5 is optimal for leaching.[117] Furthermore, in solutions at or below pH 9.36, hydrogen cyanide (HCN) is the dominant form of cyanide as well as the most toxic form.[118] Hydrogen cyanide is a gas, which means for mining operations it is imperative to maintain a high pH to prevent gaseous HCN from forming, not only for the purpose of leaching, but because it is the only way for miners to safely work with cyanide.[119] These levels of pH mean that the amount of free cyanide released is lower during the leaching process, in mining, beneficially affecting the relative toxicity of the cyanide used in mining operations.

113. *See Cyanide Chemistry*, *supra* note 12.

114. DEP'T HEALTH & AGING, *supra* note 105.

115. *Id.*

116. *See* CYANIDE IN MINING, *supra* note 92, at 3.

117. EPA, EPA 530-R-94-037, TECHNICAL REPORT: TREATMENT OF CYANIDE HEAP LEACHES AND TAILINGS (1994) [hereinafter TREATMENT OF CYANIDE], *available at* http://www.epa.gov/osw/nonhaz/industrial/special/mining/techdocs/cyanide.pdf.

118. *Cyanide Chemistry*, *supra* note 12.

119. *See generally* Adrian Smith & Debra Strusacker, *Cyanide Geochemistry and Detoxification Regulations*, *in* INTRODUCTION TO EVALUATION, DESIGN, AND OPERATION OF PRECIOUS METAL HEAP LEACHING PROJECTS 275-85 (Dirk Van Zyl et al. eds, 1988).

B. Cyanide and Heap Leaching

Sodium cyanide is very soluble in water and highly attracted to metals, which allows it first to disassociate, and then to combine with metals to dissolve the metals from their aggregate.[120] The process of disassociation and complexation of recovering metals is known as "hydrometallurgy."[121] Heap leaching is one commonly used method of extracting both low grade gold ore and gold which is scattered diffusely in the large body of host rock.[122] Mining operations that use heap leaching place the ore onto lined pads, which are sometimes even double and triple lined.[123] The pads are typically engineered with a slight grade so that the solution is deposited into a collection system where it is recovered at a later time.[124] After the ore is placed on the pad, the ore is exposed to a sodium cyanide solution, typically containing sodium cyanide in the range of 0.01% and 0.05%,[125] by pond, spray, or portable drip units.[126] In order for the leaching process to occur, where the cyanide combines with gold for later recovery, the pH of the solution needs to be between 9.5 and 11 (this level of pH is termed alkaline, also known as basic).[127] The resulting chemical reaction is then oxygen driven.[128] If the solution has a lower pH, then more free cyanide is formed, which means the cyanide would be subsequently lost through volatilization, making the solution less efficient in recovering the gold.[129]

The gold and cyanide combine during the leaching process, creating a gold-cyanide solution that is referred to as "preg-

120. *Cyanide Chemistry*, *supra* note 12.

121. *Hydrometallurgy*, ENCYC. BRITANNICA, http://www.britannica.com/ EBchecked/topic/278933/hydrometallurgy (last visited Oct. 24, 2012). *See generally* LOGSDON ET AL., *supra* note 19.

122. DEP'T HEALTH & AGING, *supra* note 105.

123. EPA, ABANDONED MINE SITE CHARACTERIZATION AND CLEANUP HANDBOOK (Aug. 2000), *available at* http://www.epa.gov/superfund/policy/remedy/pdfs /amscch.pdf.

124. *See id.*

125. *Id.*

126. *Id.*

127. *See* TREATMENT OF CYANIDE, *supra* note 117, at 21.

128. *Id.*

129. *See id.*

nant."[130] This solution is the precursor to the metallic gold obtained after the recovery process. The leaching process typically takes from weeks to months.[131] The pregnant solution is then collected or diverted to tanks or ponds, where the actual gold recovery process begins.[132]

During this recovery process, mining operations can choose to extract the gold itself in two ways: (1) adsorption, and/or (2) precipitation.[133] During adsorption, the pregnant solution is pumped into a series of columns containing activated carbon.[134] The gold-cyanide ion is adsorbed onto activated carbon granules, and then the gold is typically removed from the carbon by a stripping solution.[135] During precipitation, the pregnant solution is filtered. During this filtering, particles of unwanted, suspended solids, as well as dissolved oxygen, are removed in order to aid in the recovery process.[136] Metallic zinc dust is then added to the deoxygenated pregnant solution, where a reaction occurs that results in a gold precipitate.[137] The solution is filtered once again, removing the gold and any other precipitates which may have formed, such as silver.[138] After these processes take place, the remaining cyanide solution is referred to as "barren" and is either re-processed for future use with other ore bodies or it is treated for disposal.[139]

Depending on the mine operation, the "barren solution" and spent ore (tailings) are either treated and made subject to disposal on-site in a tailings pond, or treated and disposed of far off-site.[140] The former, on-site disposal system occurs more commonly. The processes used to treat the barren solution include (1) vo-

130. *See id.*
131. *See id.*
132. *See id.*
133. *See* EPA, EPA 530-R-94-013, TECHNICAL RESOURCE DOCUMENT: EXTRACTION AND BENEFICIATION OF ORES AND MINERALS: GOLD 2 (1994), *available at* http://www.epa.gov/osw/nonhaz/industrial/special/mining/techdocs/gold.pdf.
134. *See id* at 1-31.
135. *See id.*
136. *See id.* at 1-36.
137. *See id.*
138. *See id.*
139. *See id.* at 4-44.
140. *See id.*

latilization, (2) precipitation, (3) biodegradation, and (4) oxidation.[141] These treatments of the barren solution are necessary in order to ensure that cyanide concentrations and heavy metals in effluent are low enough to be safe for disposal.[142] *Volatilization* of hydrogen cyanide occurs when the pH of the barren solution reaches a moderate to slightly alkaline level, and occurs naturally. After the hydrogen cyanide enters the atmosphere it undergoes further reactions that produce inert compounds, which are not considered toxic to humans and the environment.[143] *Precipitation* of complex cyanides occurs when a "complexing" agent, such as iron, is added to the barren solution.[144] This process further reduces the amount of free cyanide by creating iron-cyanide complexes.[145] The iron-cyanide complexes may then undergo further reactions forming precipitates, where the cyanide is removed.[146] In *biodegradation* processes, the barren solution is exposed to oxygen-loving bacteria that decompose the various forms of cyanide into inert compounds.[147] *Oxidation* occurs when a detoxifying agent, such as hydrogen peroxide, is added to the barren solution.[148] The subsequent reaction destroys both highly toxic "free cyanide" and Weak Acid Dissociable (WAD) cyanide, while other metalloid-cyanide complexes precipitate out.[149]

When cyanide is added to the "heap," not all of it necessarily becomes available for leaching of the desired metal. Depending on the constituents of the ore body, some cyanide might also combine with other elements to form metalloid-cyanide complexes, thiocyanate (sulfur-cyanide complex), thiocyanate complexes, and cyanate.[150] This reaction occurs when the raw ore body is considered low grade, where there are relatively small amounts of gold compared to other elements, for example, sulfur or iron. In such

141. *See* LOGSDON ET AL., *supra* note 19.
142. *See id.*
143. *See generally id.* at 16.
144. *Id.* at 22.
145. *Id.*
146. *Id.*
147. *Id.*
148. *Id.* at 20.
149. *See id.* at 21.
150. *See* F. Gurbaz et al., *Biodegradation of Cyanide Containing Effluents by Scenedesmus Obliquus*, 162 J. HAZARDOUS MATERIALS 74 (2009).

cases, some of the resulting metalloid-cyanide complexes are classified as "Weak Acid Dissociable" (WAD) cyanide.[151] Weak Acid Dissociable cyanide readily forms dangerous free cyanide at moderate pH.[152] Such an occurrence is a potential problem for the surrounding area, because free cyanide is extremely toxic to humans and the environment.[153] However, miners try to avoid WAD cyanide, because WAD cyanide readily evaporates through volatilization, which makes it far less efficient at leaching gold, since the cyanide is then no longer available in the solution.

The rate at which WAD complexes dissociate and release free cyanide depends on environmental factors such as (1) temperature, (2) exposure to ultraviolet light, and (3) physical factors such as WAD concentration and pH.[154] Because WAD cyanides have an affinity to disassociate to free cyanide, they are generally perceived as being more toxic and more dangerous environmentally,[155] while thiocyanate and cyanate are comparatively less toxic than free cyanide.[156] For mine operations using cyanide, the formation of WAD cyanide is inherent due to the geologic variations of the ore, so the goal for mining operations is to prevent the WAD cyanide from forming free cyanide. With free cyanide, the cyanide itself might then be lost through volatilization, thus inhibiting the leaching of gold.

The bottom line is this: The reasonably prudent miner has an interest in ensuring that WAD cyanide does not create free cyanide, both because of a need to free the gold efficiently, and because free cyanide is the most toxic form of cyanide. In other words, it is in the miner's economic self-interest to avoid and prevent the most toxic forms of cyanide.

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151. *See* LOGSDON ET AL., *supra* note 19, at 18.
152. *See Cyanide Chemistry*, *supra* note 12.
153. *Id*.
154. *See* LOGSDON ET AL., *supra* note 19, at 23.
155. *See id.* at 15-18*; see also Cyanide Chemistry*, *supra* note 12.
156. *See* AGENCY FOR TOXIC SUBSTANCES & DISEASE REGISTRY, PUBLIC HEALTH STATEMENT FOR CYANIDE (2006), *available at* http://www.atsdr.cdc.gov/phs/phs.asp?id=70&tid=19.

C. The Biologic Toxicity of Cyanide

The toxicity of cyanide to living organisms is highly variable. It is dependent on many factors, including cyanide concentration, ore-body constituents, pH of the receiving medium (soil or water), temperature, and exposure to sunlight.[157] Some of these variables are within the control of mining operations; some are not. The central reality of cyanide chemistry for mining operations is that free cyanide and WAD cyanide (which helps create free cyanide) are the most toxic forms of cyanide, while complexed-cyanide, such as iron cyanide, and thiocyanate, tend to be less toxic. The reason for this toxicity distinction is because when free cyanide is ingested, inhaled, or absorbed through the skin, the negative cyanide ion has an affinity to attach to the red blood cells and cause the organism to suffocate.[158] This suffocation occurs because the red blood cells are no longer able to release the oxygen to the tissues and organs.[159] Cyanide's bad reputation environmentally is due to cyanide compounds that break down into free cyanide, since these are the chemicals that are considered highly toxic to most living organisms.[160] The corollary to this reality is that because only "biologically available" cyanide is toxic, if cyanide is strongly combined with another material and does not separate to release free cyanide, it is then *not* biologically available and is less toxic.[161]

When considering cyanide toxicity, other factors which are important include: water pH, temperature, and available oxygen.[162] For aquatic organisms it is also important to factor in the

157. *See* RONALD EISLER, U.S. FISH & WILDLIFE, SERV., CYANIDE HAZARDS TO FISH, WILDLIFE, AND INVERTEBRATES: A SYNOPTIC REVIEW 29 (1991) [hereinafter CYANIDE HAZARDS TO FISH, WILDLIFE, AND INVERTEBRATES], *available at* http://www.pwrc.usgs.gov/infobase/eisler/chr_23_cyanide.pdf.

158. *See id* at 3.

159. *Id.*

160. *See* Angelina Souren, *Living with Cyanide,* GEOCHEMICAL NEWS, Oct. 2000, at 16.

161. *See* Munaswamy David et al., *Assessment of Sodium Cyanide Toxicity on Freshwater Teleosts,* 2 RECENT RES. SCI. & TECH. 16 (2010), *available at* http://www.researchgate.net/publication/200822873_Assessment_of_Sodium_Cyanide_Toxicity_on_Freshwater_Teleosts.pdf.

162. *See* CYANIDE HAZARDS TO FISH, WILDLIFE, AND INVERTEBRATES, *supra* note 157, at 29.

life stage, health, and type of potentially affected species.[163] For example, juvenile and adult freshwater fish are more susceptible to the fatal effects of cyanide when the water body has low pH and little available oxygen, while some species of fertilized eggs are more resistant if exposed to cyanide early in the development of the embryo.[164] In addition, boney fish are more susceptible to the fatal effects of cyanide than invertebrates,[165] especially when the freshwater system has a low temperature; however, the invertebrates are more susceptible at higher temperatures.[166] This correlation between cyanide used in mines and associated environmental risk means that only aquatic organisms would likely be affected after an accidental spill from a mining operation. Mammals and especially birds are more likely to become exposed to the cyanide by misinterpreting ponding on a leach pad or a tailings pile as an actual water or food source.[167] Therefore, the chief environmental issue for miners using cyanide is the risk to aquatic life. And, to prevent harm to aquatic organisms, mines using cyanide need to both prevent accidental spills, and mitigate environmental damage if there is a spill.

D. Routes of Exposure and Levels of Toxicity

If there were to be an accidental cyanide release into the environment from a mining operation, the most likely route of exposure to cyanide for most organisms is by way of ingestion or adsorption.[168] Because free cyanide evaporates into the atmosphere at a moderate pH, fatalities due to inhalation of cyanide gas is less common for in-process cyanide solutions. Mining operations maintain the solution at a higher pH for purposes of leaching and worker safety, and therefore the cyanide is not biologically available for inhalation at this stage.[169] Once the solution becomes

163. *See id.*
164. *See id.* at 27.
165. *See* David et al., *supra* note 161, at 2.
166. *See Sodium Cyanide Hazards to Fish*, *supra* note 62, at 6.
167. *See* LOGSDON ET AL., *supra* note 19, at 28; *see also,* DEP'T HEALTH & AGING, *supra* note 105, at xxx.
168. *See* CYANIDE HAZARDS TO FISH, WILDLIFE, AND INVERTEBRATES, *supra* note 157, at 9.
169. *See* LOGSDON ET AL., *supra* note 19, at 31.

barren or spent, as a result of the recovery process, the solution may reach pH levels that will liberate some free cyanide and WAD cyanide into the atmosphere.[170] Other factors affect the rate at which the cyanide is lost to the atmosphere. Some conditions, such as impoundment (pond) depth and surface area will play a role in releasing the cyanide into the air.[171] For instance, a shallow pond with a large surface area will have a higher rate of volatilization compared to a small, deep pond. After a spill, this reaction would also be dependent on temperature and available oxygen in the pond or surface water.

Animal toxicity through ingestion or adsorption is primarily dependent on the concentration of the cyanide, in both the in-process solutions and spent solutions at a mining operation, as well as species of cyanide present, because WAD cyanides will break down in the stomach of the animal releasing toxic free cyanide. However, if the concentration of cyanide is relatively low, then the organism would possibly be able to convert the cyanide to less toxic thiocyanate.[172] Chronic exposure to thiocyanate may have an adverse effect on the thyroid gland of most living organisms.[173]

Other important factors contributing to toxicity are ore-body constituents, which relate to stable and weak complexation of cyanide to minerals, and exposure to ultraviolet light.[174] During the cyanide leaching process at mining operations, some cyanide will combine to form metalloid-cyanide complexes.[175] Many of the metalloid cyanide complexes are considered very stable and therefore less toxic compounds compared to free cyanide. Under typical mining conditions, cyanide will combine to form iron-cyanide complexes, as well as copper-cyanide complexes, when

170. *See* NEEDHAM, *supra* note 15, at 14 (2003).

171. *See* D.B. Donato et al., *A Critical Review of the Effects of Gold Cyanide Bearing Tailings Solutions on Wildlife*, 33 ENV'T INT'L 974-84 (2007) [hereinafter Donato et al., *A Critical Review*].

172. *See id.*; *see also* D.B. Donato et al., *The Protection of Wildlife from Mortality: Hypothesis and Results for Risk Assessment*, 34 ENV'T INT'L 727-36 (2008).

173. *See* U.S. DEP'T OF HEALTH & HUMAN SERVS., TOXICOLOGICAL PROFILE FOR CYANIDE 117 (2006), *available at* http://www.atsdr.cdc.gov/toxprofiles/tp8-p.pdf.

174. *See* LOGSDON ET AL., *supra* note 19, at 17-18.

175. *See id.* at 17.

these metals are present in the ore-body.[176] Ordinarily, iron-cyanide complexes are considered very stable and are therefore less toxic.[177] Complexation of cyanide is extremely important when considering toxicity.[178] Cyanide has an affinity to combine with metals that are readily available in soils and ores. But the complexing behavior of cyanide also reduces the mobility of cyanide in the environment, which is significant because less movement further reduces exposure.[179]

On the other hand, exposure to ultraviolet light will break down iron-cyanide, releasing toxic free cyanide.[180] Under these conditions, iron-cyanide could become lethal if ingested or adsorbed by an organism after this reaction occurs, because free cyanide has then become biologically available.[181] Nonetheless, the potentially toxic free cyanide may be made far less lethal through volatilization, depending on the solution's pH, and biodegradation by microbes.[182]

Copper-cyanide complexes are classified as WAD cyanide.[183] Although copper-cyanide complexes may not degrade under exposure to ultraviolet light, they do break down into toxic free cyanide in moderate to low pH.[184] This chemical and biological reaction is important because, even if the solution at a mining operation is maintained at a high pH, if it is ingested by an organism, the low pH in the organism's stomach will release free cyanide. Depending on the concentration of the cyanide ingested, the cyanide then may be fatal to that organism.[185]

176. *See id.* at 16.
177. *See Cyanide Chemistry*, *supra* note 12, at 1.
178. *See* LOGSDON ET AL., *supra* note 19, at 77-78.
179. *See id.*
180. *See* CYANIDE HAZARDS TO FISH, WILDLIFE, AND INVERTEBRATES, *supra* note 157, at 19.
181. *See id*.
182. *See id*.
183. *See id*.
184. *See* LOGSDON ET AL., *supra* note 19, at 22.
185. *See* Donato et al., *A Critical Review*, *supra* note 171.

E. Acute and Long Term Exposure to Cyanide

For organisms that are exposed to a high, lethal concentration of cyanide, whether it is by way of inhalation or ingestion/adsorption, the effect is always fatal. The time it takes for the organism to succumb to the cyanide depends on the type of cyanide to which the organism was exposed.[186] For example, if the organism ingested a high concentration of WAD cyanide, it may take slightly longer than a similar organism that ingested a high concentration of free cyanide.[187] However, if an organism is exposed to a sub-lethal dose of cyanide, most living organisms are able to metabolize the cyanide into less toxic thiocyanate, and eventually expel it from the organism's body through urine.[188] In other words, *exposure to wildlife from cyanide*, even aquatic life, *is not necessarily fatal.*

Sub-lethal, acute exposure to cyanide does not create long term effects in organisms, and unlike mercury, it is not known to bio-accumulate.[189] Conversely, if the exposure is not acute, but long term, for sub-lethal doses there is not an acute reaction because organisms are able to convert the cyanide to less toxic thiocyanate.[190] Some studies have shown long term exposure to cyanide may result in decreased function of the thyroid gland and nervous system, increasing vulnerability to predation and infection, and in some susceptible aquatic groups, will create reproduction problems.[191] These kinds of effects are important to consider for those instances where surface waters or drinking water supplies have been completely compromised by continued low concentrations of cyanide from mining operations.

186. *See generally Sodium Cyanide Hazards to Fish*, *supra* note 62.

187. *See id.*

188. *See* Stephen R. Griffiths et al., *Factors Influencing the Risk of Wildlife Cyanide Poisoning on a Tailings Storage Facility in the Eastern Goldfields of Western Australia,* 72 ECOTOXICOLOGY & ENVTL. SAFETY 1579-86 (2009).

189. *See* Ronald Eisler & Stanley N. Wiemeyer, *Cyanide Hazards to Plants and Animals from Gold Mining and Related Waters*, 183 REVS. OF ENVTL. CONTAMINATION & TOXICOLOGY 21 (2004).

190. *See Sodium Cyanide Hazards to Fish*, *supra* note 62, at 57.

191. *See id.* at 59, 65.

F. Environmental Fate of Cyanide in the Environment

There is good news for mining operations reliant on cyanide and there is an important biological reality that should be considered by those who oppose cyanide-dependent mines. Because of the chemical properties of cyanide, when it is accidentally released it typically does not persist in the environment, due to volatilization, complexation, and degradation by microbes.[192] In water, cyanide is present as free cyanide, WAD cyanide, simple cyanide, or strongly complexed cyanide, such as iron-cyanide. Due to volatilization, exposure to ultraviolet light, degradation by microbes (biodegradation), and the presence of oxygen, cyanide does not persist in surface waters.[193] To that end, when there have been spill occurrences involving cyanide where long term toxic environmental effects are observed, these environmental harms *are usually not due to the cyanide*, but instead are usually related to heavy metal toxicity and oxidation of metal sulfides, creating what is known as acid mine drainage, as observed at the Summitville Mine in Colorado.[194]

For example, consider the results of water and sediment sampling conducted by the United Nations in collaboration with the countries most affected by the cyanide spill at Baia Mare (Romania, Hungary, and the Federal Republic of Yugoslavia) where total loss of phyto- and zoo-plankton organisms was observed before the contamination plume was flushed from the system.[195] This sampling showed that recovery of these organisms occurred just days or hours after the contamination moved down the river system.[196] This finding is significant because zooplankton organisms are thought of as bio-indicators of watershed

192. *Id.* at 57.

193. *See* LOGSDON ET AL., *supra* note 19, at 16, 19-22.

194. *See generally* B. YARAR, CYANIDES IN THE ENVIRONMENT AND THEIR LONG-TERM FATE 86 (2001).

195. *See generally* U.N. ENV'T PROGRAMME, CYANIDE SPILL AT BAIA MARE ROMANIA: UNEP/OCHA ASSESSMENT MISSION (2000) [hereinafter CYANIDE SPILL], *available at* http://reliefweb.int//sites/reliefweb.int/files/resources/43CD1D010F030359C12568CD00635880-baiamare.pdf.

196. *See id.* at 33.

health.[197] Analysis of the results showed that toxicity levels in sediment decreased the further the distance from the spill site, indicating that toxic sediments did not migrate far from where the plume entered the river system.[198] In addition, water samples collected to determine the quality of drinking water after the spill did not show detectable levels of toxic free cyanide or WAD cyanide in Romania, Hungary, or the Federal Republic of Yugoslavia approximately one month after the spill.[199] This observation is consistent with cyanide's chemical nature to readily volatize and complex with minerals making the toxic form of cyanide unavailable. The most toxic form of cyanide, free cyanide, was not detected.[200] Soil samples collected along the watershed showed high levels of heavy metals,[201] which, unlike cyanide, do persist and could lead to long-term negative effects on the ecosystem.[202]

In contrast to surface waters, because groundwater lacks ultraviolet light and has less available oxygen, cyanide will persist for longer periods of time if it works its way underground.[203] Cyanide in soil is generally not biologically available because it is either complexed with metals, degraded by microbes, or lost through volatilization. In addition, soils are generally not able to adsorb the negative cyanide ion, which means the cyanide will usually leach into the groundwater where oxygen loving and non-oxygen loving microbes degrade the cyanide.[204] Table I summarizes the fate of cyanide in the environment by various reactions.

197. *See* Zannatul Ferdous, et al. *A Review: Potentiality of Zooplankton as Bio-indicator,* 6 AM. J. APPLIED SCIS. 1817 (2009).

198. CYANIDE SPILL, *supra* note 195, at 37.

199. *See id.* at 38-39.

200. *See id.*

201. *See id.* at 37.

202. *See* WORLD HEALTH ORG., HEALTH RISKS OF HEAVY METALS FROM LONG-RANGE TRANSBOUNDARY AIR POLLUTION 5 (2007).

203. *See* I. Gagnon et al., *Natural Attenuation Potential of Cyanide in Groundwater Near a SPL Landfill*, in PROCEEDINGS, THE 8TH INTERNATIONAL SYMPOSIUM ON ENVIRONMENTAL ISSUES AND MANAGEMENT OF WASTE IN ENERGY AND MINERAL PRODUCTION SWEMP (A.G. Pasamehmetoglu et al. eds., 2004).

204. *See Sodium Cyanide Hazards to Fish*, *supra* note 62, at 56.

Table 1.
Environmental Pathways of Cyanide

Affected Medium	Possible Reactions	Fate in the Environment	Toxicity
Soil Surface Water Ground Water	Complexation	Formation of ionic complexes	Varies: depends on type of complex formed; i.e. WAD complex or a toxic metalloid-cyanide complex
Soil Surface Water Ground Water	Precipitation	Formation of insoluble precipitates by iron-cyanide complexes	Not considered Toxic
Soil	Adsorption	Binding of cyanide and cyanide complexes to organic and inorganic material, usually in soil	Stable but a precursor to other reactions that occur in soil
Soil Surface Water	Oxidation	Formation of cyanate	Varies depending on concentration
Soil Surface Water	Volatilization	Formation of hydrogen cyanide gas	Fatal if inhaled in high concentrations
Soil Surface Water	Biodegradation*	Formation of ammonia by microbes	Varies depending on concentration
Ground Water	Hydrolysis**	Formation of formic acid or ammonium formate	Not considered Toxic
Soil Surface Water	Photo-decomposition	Formation of free cyanide from iron-cyanide complexes	Varies depending on concentration

Table 1: Reflects pH conditions typically found in natural systems
* Under oxygenated conditions
** Under non-oxygenated conditions

IV. CYANIDE FEARS AND RESULTING REGULATORY RESPONSES

A. Mining Accidents and Cyanide.

If one collects data summarizing environmental incidents involving mining operations from all causes over the past fifty years, only twelve out of sixty-seven environmental incidents of "meaningful proportions," that is environmentally significant, occurred as a result of cyanide, or about three cyanide spills per decade world-wide.[205] And, of thirty-three "significant" mining-related environmental incidents worldwide between 1975 and 2003, only nine primarily involved cyanide.[206] The reality of cyanide spills from mines can perhaps best be revealed by considering the actual spills themselves. A review of these various cyanide spills seems to yield three conclusions. First, mining accidents involving cyanide are relatively rare; despite their highly publicized nature, cyanide spills are usually not responsible for either long-term, or widely-felt, ecological damage. Second, the primary reason for these uncommon cyanide spills stems from mine operator error; there is nothing inherently unstable about cyanide that suggests that its use inevitably causes environmental harm. Third, even if the environment is adversely affected by a cyanide release, while there may be short-term environmental harm there typically is no permanent, long-lasting ecosystem change.

Baia Mare, Romania. The most notable cyanide spill occurred in January 2000, when a tailing pond retention dam ruptured at the Aurul Mine near Baia Mare, Romania.[207] The spill caused 100,000 cubic meters of liquid and suspended waste—containing 50 to 100 tons of cyanide, along with copper and other heavy metals—to flow into the Tisza River, a tributary to the Danube River.[208] Over a period of four weeks, the spill traveled

205. *See* Doug Hadfield, *A Cyanide Story: Are We Doing Enough to Prevent Cyanide Spills?*, MINING & MONEY (2008), *available at* http://www.stockhouse.com/columnists/2008/april/28/a-cyanide-story--are-we-doing-enough-to-prevent-cy.

206. *See* NEEDHAM, *supra* note 15, at 5.

207. *See generally* CYANIDE SPILL, *supra* note 195.

208. *See* CYANIDE UNCERTAINTIES, *supra* note 11, at 4.

about 2,000 kilometers down the Danube River catchment—through Romania, Hungary, the Federal Republic of Yugoslavia, and Bulgaria—before eventually flowing into the Black Sea.[209]

The United Nations Environmental Program (UNEP) released its preliminary report on the Baia Mare spill in March of 2000. This UNEP report reached four important conclusions. First, the rupture of the retention dam was probably caused by a combination of inherent design defects, unforeseen operating conditions, and unexpected bad weather.[210] Second, "Hungarian officials estimated that 1,240 tons of dead fish were present along the Tisza river after the spill."[211] Third, four weeks later and 2,000 kilometers away from the spill, the cyanide plume was measureable at the Danube Delta in Romania.[212]

Operational factors which lead to the Baia Mare incident include faulty processing plant and tailings storage facilities, lack of contingency planning and emergency preparedness, and inadequate chemical procedures.[213] If attention had been paid to any of these issues, the spill either would not have occurred in the first place, or it would not have been so damaging to downstream aquatic life.

Summitville Mine, Colorado. The Summitville Gold mine was responsible for contaminating seventeen to twenty-two miles of the Alamosa River with cyanide and other toxic and heavy metals.[214] Due to financial insolvency, Summitville Consolidated Mining Co., Inc. had abandoned the site with a failed containment and treatment system, leaving 150 to 200 million gallons of cyanide-laced water leaking from unsealed and untreated leach ponds, and unable to be mitigated because of the failed contain-

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209. *Id.*
210. *See id.*
211. *See id.*
212. *See id.*
213. Fritz Balkau, *Learning from Baia Mare,* ENV'T & POVERTY TIMES (Mar. 2005), http://www.grida.no/files/publications/environment-times/kobetimes_0405.pdf.
214. *See* Geoffrey S. Plumlee & Pat Edelman, *The Summitville Mine and Its Downstream Effects*, U.S. GEOLOGICAL SURVEY, http://pubs.usgs.gov/of/1995/ofr-95-0023/summit.htm (last updated July 11, 1995); CYANIDE UNCERTAINTIES, *supra* note 11, at 5.

ment and treatment system.[215] The toxic spill killed nearly all aquatic life along that stretch of the river, which also adversely affected the nearby Terrance Reservoir.[216] Although the Summitville mine still stands as one of the most expensive Superfund mine-site cleanups,[217] the environmental damage directly attributable to cyanide was temporary. The long-lasting consequences of this spill were due to ARD and other toxic minerals that have continuously spread down the Alamosa River.[218]

Kumtor Mine, Kyrgyzstan. In 1998, a truck transporting cyanide to the Kumtor mine in Kyrgyzstan crashed on a bridge and plunged into the Barskoo River, spilling almost two tons of cyanide into the waterway.[219] While cyanide caused some temporary environmental harm, the river soon recovered.[220]

Zortman-Landusky Mine, Montana. Environmental groups allege that Pegasus Corporation's Zortman-Landusky mine in Montana—the first large-scale cyanide heap leach mine in the United States—has produced over a dozen cyanide spills, including one in 1982 that released approximately 50,000 gallons of cyanide solution that contaminated the local community's water supply.[221] However, subsequent reports indicate that non-cyanide related ARD continues to pollute ground and surface waters in the area, not cyanide.[222]

Ghana, Africa. Over the last fifteen years, multiple cyanide spills of varying magnitude have occurred at gold and silver mines in Ghana. For example, repeated releases of cyanide caused by negligent management of a tailings pond that occurred

215. Plumlee & Pat Edelman, *supra* note 214.

216. *Id.*

217. *Id.*

218. *Id.*

219. CYANIDE UNCERTAINTIES, *supra* note 11, at 7-8 (some individuals question the findings of the report conducted after the spill because they are believed to be biased; however these criticisms to the report have yet to be validated).

220. *Id.*

221. Karen Brandon, *New Laws Tempering Gold-mining Prospects*, CHI. TRIBUNE, Feb. 21, 1999, http://articles.chicagotribune.com/1999-02-21/news/9902210306_1_mining-industry-montana-environmental-information-center-mining-period/2.

222. Erin Klauk, *Environmental Impacts at Fort Belknap from Gold Mining,* INTEGRATING RES. & EDUC., http://serc.carleton.edu/research_education/nativelands/ftbelknap/environmental.html (last visited Mar. 2013).

at the Ahafo Mine in Asutifi District of Ghana, reportedly resulted in large fish kills in surrounding wetlands.[223] The Newmont Gold Company was also accused of covering up incidents and falsifying reports of cyanide spills at their mine in Ghana.[224] After local residents sought legal action, Newmont settled with the government and paid $4.9 million in fines for damages.[225]

Guyana Cyanide Spill. In 1995, a tailings dam collapsed at a gold mine in Guyana, releasing an estimated 2.3 billion liters of cyanide waste.[226] This spill affected approximately 23,000 Guyanese residents that were dependent upon the waterways for fishing, washing, bathing, and transportation.[227] In response to the toxic cyanide spill, Guyanese residents filed a $69 million suit against the gold refiner in a Canadian Court, but the suit was dismissed because the Canadian court held that Guyana, the site of the major spill, was the more appropriate forum.[228] Subsequently, Guyanese residents filed a $100 million class action suit in Guyana, which was also dismissed.[229] An attorney for the plaintiffs allegedly affected by the spill explained that the problems associated with this lawsuit were due to the fact that the Guyanese residents "didn't trust their own judicial system and

223. *See* Dorothy Kosich, *Ahafo Mine Cyanide Spill Prompts NGOs to Question Intl. Cyanide Code Validity*, MINEWEB (Jan. 22, 2010), http://www.mineweb.com/mineweb/view/mineweb/en/page72068?oid=96302&sn=Detail.

224. *See* Nick Magel, *Wikileaks Cables Reveal U.S. Mining Co. Negligence in Ghana Cyanide Spill*, EARTHWORKS (Sept. 12, 2011), http://www.earthworksaction.org/earthblog/detail/wikileaks_cables_reveal_us_mining_co_negligence_in_ghana_cyanide_spill.

225. *See id.; see also Newmont Found Guilty of Major Cyanide Spill at Ghanaian Mine*, ASSOCIATED PRESS (Jan. 21, 2010), http://www.minesandcommunities.org/article.php?a=9828.

226. *See* Christine R. Thompson, *A Multifaceted Approach to the Regulation of Cyanide in Gold Mining Operations*, 29 SUFFOLK TRANSNAT'L L. REV. 79, 101-02, n.114, 115 (2005).

227. Pratap Chatterjee, *ENVIRONMENT: Lawsuit Over Guyana Mine Calls for Company to Cleanup*, INTER PRESS SERV., Mar. 28, 1997, http://www.ipsnews.net/1997/03/environment-lawsuit-over-guyana-mine-calls-for-company-to-cleanup/.

228. *See* MICHAEL WELTERS, THE BATTLE TO STOP CORPORATE HARM: CORPORATE USE OF THE CANADIAN LEGAL SYSTEM (1997), *available at* http://www.hartford-hwp.com/archives/44/119.html.

229. *See* Thompson, *supra* note 226, at n.115.

wanted the case heard in Canada."[230] As a result, there has been no judicial conclusion about how much harm was in fact caused by the 1995 spill, or by the cyanide release.

B. Why Did These Accidents Occur?

When cyanide is used in relation to mining operations, one inchoate fear is that, by its very toxic nature, cyanide in mines will inevitably, or probably, contaminate air, water, and soil, cause harm to wildlife, and even produce human rights violations.[231] The concern is that the cyanide will be unable to be contained, and once it is released, it will adversely affect ecosystems, particularly waters.[232] If one cuts through these myths, two different truths emerge.

The first truth is that, despite its ubiquitous use in mines throughout the United States, mining releases are rare and relatively insignificant sources of cyanide.[233] Most of the cyanide and related poisonous compounds entering the natural environment and its surface waters originate from effluents discharged by municipal sewage treatment plants, and from iron cyanide used in road salt.[234] Similarly, millions of liters of chemical fire retardants, containing 400 tons of iron cyanide, are sprayed on lands to fight forest fires annually.[235] By contrast, the total amount of cyanide released into surface waters of the United States from all mining and metals-related sources is typically between forty to fifty tons.[236]

The second truth is that cyanide spills from mines, when they occur, are not the result of some inherent toxic character of the chemical itself; instead, as noted above in Part IV(A), virtually all cyanide spills have very human causes. There are three recurrent reasons for these occasional spills: (1) The lack of a plan encompassing dynamic site water balance and comprehensive

230. *Id.* at 101-02.
231. *See* Mudder & Botz, *supra* note 26, at 64-66.
232. *See* SZILÁGYI, *supra* note 52, at 4.
233. *See generally* Hadfield, *supra* note 205, at 56.
234. *See* Mudder & Botz, *supra* note 26, at 64.
235. *See id.* at 66.
236. *See id.* at 64.

water management; (2) the implementation of improper water treatment capabilities; and (3) the absence of both integrity and secondary containment infrastructures within the solution conveyance system.[237] If cyanide is released during mining operations, it is usually from the following sources, each of which can either be designed or regulated to ensure the cyanide is contained:

1. during transportation of sodium cyanide to site of use
2. tailings dam failures
3. heap (and dump) failures
4. seepage from heaps, dumps, and impoundments
5. clandestine usage by unauthorized artisanal miners.[238]

Major cyanide accidents at gold mines throughout the world derived from cyanide transport (14%), pipe failure (14%), and tailings dam mishaps (72%).[239] However, few of these incidents involving cyanide resulted in real or persistent environmental damage. When miners have experienced dam failures, or when tailings ponds and heap pads seep, the real environmental problem lies not with cyanide, but with the release of toxic and heavy metals such as lead, cadmium, zinc, copper, and mercury. The Summitville Colorado Superfund site, discussed in Part IV(A) above, is a case in point.[240] The effort to clean up that mine disaster involves extensive attention to acidic rock drainage (ARD) and release of heavy metals other than cyanide.[241] The cost of cleanup for the Summitville mine has been estimated to be in excess of $100 million.[242] But that cost is not due to cyanide contamination; it is due to the long lasting effects from ARD and exposure of heavy metals.[243] What persists in the environment is

237. *See* TERRY I. MUDDER, CYANIDE SPILLS PREVENTION AND RESPONSE 1 (last visited Nov. 2, 2012), *available at* http://www.infomine.com/publications/docs/MudderT.pdf.

238. *See* YARAR, *supra* note 194, at 86; *see also*, THOMAS HENSTCHAL ET AL., MINING MINS. & SUSTAINABLE DEV., GLOBAL REPORT ON ARTISANAL & SMALL SCALE MINING 36- 37 (2002), *available at* http://pubs.iied.org/pdfs/G00723.pdf.

239. *See* SZILÁGYI, *supra* note 52, at 5.

240. *See* YARAR, *supra* note 194, at 86.

241. *See* Plumlee & Edelman, *supra* note 214.

242. *See* YARAR, *supra* note 194, at 86.

243. *See* Plumlee & Edelman, *supra* note 214.

not cyanide, but the effects of mining operations that expose waters and aquatic organisms to other more long-lasting elements.[244]

C. Regulatory Responses to Fears About Cyanide

The science and history of cyanide and the environment suggest that cyanide use usually does not preclude long term harm, especially if miners use it in a way that is most conducive to leaching gold and copper from rock. Nonetheless, fears about the effects of cyanide on ecological resources have triggered an array of regulatory responses. Three categories of regulation have emerged due to fears associated with well-publicized cyanide spills, and subsequent concerns about the risks of cyanide heap leaching on the environment. The least common reaction to the perceived threat of cyanide is to establish voluntary codes and non-binding best practice standards. When fears increase, governments may intensify the regulatory limits by requiring strict preventative techniques and large upfront financial assurances to cover the cleanup costs of any cyanide spill. When the environmental risks seem over-whelming, the simplest (and most brutal) approach is to impose complete bans on cyanide.

These three levels of regulatory responses parallel rising levels of perceived risks. The direction that the regulatory scale tips often turns on the extent of historical damage caused by mining activities. If risk does not appear too high, then relaxed regulation reflects the potential opportunity for economic return that follows by allowing cyanide to be a component of mineral development. But, when mining and cyanide engender sufficient fear, retaliatory and prohibitory regulatory measures and bans are imposed.

a. Voluntary Codes and Best-Practice Standards

In 2001, the mining industry self-regulated when public concern intensified about the use of cyanide by developing the Inter-

244. *See* YARAR, *supra* note 194, at 88 (demonstrating the short persistence period of cyanide compared with the long periods of other mining chemicals).

national Cyanide Management Code (Code).[245] This voluntary Code allows mine operators to demonstrate their commitment to safe, responsible use of cyanide. Development of the Code was largely motivated in response to public scrutiny of mining following the catastrophic cyanide spill of January 2000, in Baia Mare, Romania, which resulted in substantial, albeit temporary, environmental damage along the Danube River catchment.[246] The spill was attributed to defective impoundment construction, negligent operation, and lack of regulatory oversight.[247]

Following the Baia Mare catastrophe, an International Workshop was held to address the need for a uniform code of regulations over cyanide use in mine operations.[248] This workshop led to the development of the Code, with the assistance of the International Cyanide Management Institute (ICMI), and other multi-stake holders charged with overseeing development, implementation, and modification of the Code.[249] In 2005, the Code became operational.[250]

The Code is a completely voluntary initiative for the gold mining industry, focused exclusively on the safe management of cyanide that is produced, transported, and used for the recovery of gold, and intended to complement existing regulatory requirements.[251] The Code does not contravene regulations and laws of the applicable political jurisdiction; nor does it create, establish,

245. *See* Donato et al., *A Critical Review*, *supra* note 171, at 974-84 (2007); *see generally* U.N. ENV'T PROGRAMME, A WORKSHOP ON INDUSTRY CODES OF PRACTICE: CYANIDE MANAGEMENT (2000) [hereinafter WORKSHOP ON INDUSTRY CODES] (The Code was developed during a two-day workshop in Paris sponsored by the "United Nations Environment Programme" (UNEP) and "International Council on Metals and the Environment" (ICME). Attendees included governmental organizations, nongovernmental organizations, environmental groups, cyanide producers, mining companies, and mine industry experts).

246. *See supra* text accompanying notes 207 to 213 (referring to the notes in Part III.F).

247. *See* Edward M. Green & Paul W. Bateman, *A Case Study of a New Voluntary Best Practices Code: Lessons for Industry?*, *in* INTERNATIONAL CYANIDE MANAGEMENT CODE, ROCKY MOUNTAIN MINERAL LAW FOUNDATION 6 (2006).

248. *See* WORKSHOP ON INDUSTRY CODES, *supra* note 245.

249. *See id.*

250. *See* DAWN H. GARCIA, SRK CONSULTING, AN INTRODUCTION TO THE INTERNATIONAL CYANIDE CODE 6 (2009), *available at* http://www.srk.com/files/File/papers/Compliance-Cyanide-Code(1).pdf.

251. *See* WORKSHOP ON INDUSTRY CODES, *supra* note 245.

or recognize any legally enforceable obligations or rights on the part of the signatories, supporters, or any other parties.[252]

Since its inception in 2001, more than 20 gold mining companies, representing 100 gold mines in 27 countries, plus 12 cyanide producers and 16 cyanide transporters, have become Signatory Companies.[253] While most large-scale gold companies have implemented the Code, there has been little participation on the part of smaller mine operations.[254] Nevertheless, as seen in Australian mines, implementation of the Code has reduced the environmental impacts typically associated with mining.[255]

b. Regulate Through Prevention Techniques and Upfront Financial Assurances

The majority of developed countries where cyanide is used in mining have adopted two complementary legal approaches: (1) implementation of specific regulatory standards and limitations on cyanide use during mining, and (2) imposition of requirements, prior to mining, that mine operators post upfront financial assurances to cover the costs of any cyanide spill.

The European Parliament and Council (EU) has set the most stringent cyanide limits for tailings ponds in the world by adopting Directive 2006/21/EC on the management of waste from mineral extraction operations.[256] Article 12(6) of the Directive requires that the concentration of WAD cyanide (weak acid dissociable cyanide forms the most dangerous type of cyanide) in the pond be reduced to the lowest level possible using best available techniques.[257] All mines started after May 1, 2008 may not discharge waste containing over 10ppm WAD cyanide, while

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252. *See Use of Cyanide in the Gold Industry,* INT'L CYANIDE MGMT. CODE, http://www.cyanidecode.org/cyanide_use.php (last visited Nov. 6, 2012); NEEDHAM, *supra* note 15, at 11.

253. *See* Garcia, *supra* note 250, at 1.

254. *See generally* DEP'T OF RES., ENERGY & TOURISM, LEADING PRACTICE SUSTAINABLE DEVELOPMENT PROGRAM FOR THE MINING INDUSTRY: CYANIDE MANAGEMENT 19-20 (2008), *available at* http://www.ret.gov.au/resources/Documents/LPSDP/LPSDPCyanideHandbook.pdf.

255. *See id.* at 15.

256. *See* Council Directive 2006/21/EC on the management of waste from extractive industries and amending Directive 2004/35/EC, 2006 O.J. (L 102).

257. *See id.*

mines with a permit or in operation before that date are initially limited to 50ppm, dropping to 25ppm by 2013 and 10ppm by 2018.[258] In addition, Article 14 requires that mine operators also put in place financial guarantees to ensure cleanup once the mine has finished operations.[259] Fortunately for the mining industry, it was on the basis of these strict regulations that the EU eventually rejected the European Parliament's (EP) 2010 resolution to ban the use of cyanide, which would have effectively put an end to the gold mining industry in all of the member states.[260]

In the United States, no federal statute directly addresses cyanide use in the mining industry. However, state and federal agencies have developed regulations and performance standards for cyanide leaching operations at mine sites on state or federal land. Pursuant to the Federal Land Policy and Management Act of 1976 (FLPMA),[261] the Bureau of Land Management (BLM) has established a national cyanide management policy that requires state BLM offices to prepare a cyanide management plan before issuing permits to any mine that will process minerals with cyanide.[262] The BLM's national cyanide policy directs that all mines with cyanide leaching operations ensure environmental protection through containment and neutralization of solution lethal to humans or wildlife.[263] The agency commits to inspecting mine operations four times a year if the mine uses cyanide leaching processes, or if there is a significant potential for acid rock drainage.[264] The BLM also requires financial assurances, often in the form of surety bonds, to cover the estimated costs of decommissioning and neutralizing all cyanide facilities prior to issuing a permit for mine closure.[265] However, this Federal cyanide policy does not include any mechanisms for enforcing implementation at mine sites.[266] As a result, the ultimate responsibility of manag-

258. *See id.*
259. *See id.*
260. *See EU Commission Refuses Ban on Cyanide in Gold*, MINES & CMTYS. (July 17, 2010), http://www.minesandcommunities.org/article.php?a=10246.
261. *See* 43 U.S.C. §§ 1701-33 (2006).
262. *See* 43 C.F.R. § 3809.420 (2012).
263. *See id.* § 3809.420(b).
264. *See id.* § 3809.600(b).
265. *See id.* § 3809.500.
266. *See* CYANIDE LEACH MINING PACKET, *supra* note 20.

ing cyanide facilities at mine sites lies with state regulatory agencies.

The state of Nevada has the most comprehensive set of cradle-to-grave cyanide regulations, which should not be surprising given that mining in the state accounts for 75% of total gold production in the United States, where most of these gold mines rely on cyanide.[267] In accordance with the BLM's Cyanide Policy, and Nevada Department of Environmental Protection (NDEP) regulations, cyanide facilities must be designed for zero discharge to both surface water and groundwater. These facilities must be constructed with impermeable containment systems or liners to prevent seepage.[268] Tailings impoundments must also be fully lined with primary and secondary layers of impermeable synthetic liners.[269] Heap leaching pads must also be constructed on top of an engineered liner system which provides containment equal to or greater than that provided by a synthetic liner, resting on a layer of compacted soil, sufficiently impermeable to contain cyanide solution during heap leaching.[270] Further, in areas where the groundwater is considered "near surface," heap leaching facilities may require a liner system with a higher level of engineered containment, in order to prevent seepage.[271] In addition, cyanide mineral processing facilities must meet minimum design criteria.[272]

The state of Idaho has addressed the issue of ensuring safe cyanide leaching operations by requiring mine operators to provide upfront financial assurances.[273] The 2005 amendment to the Idaho Surface Mining Act of 1971 mandates that mines using cyanide leaching facilities provide financial assurances sufficient to cover the costs of closing approved cyanide operations and facilities, as well as general reclamation of the mine site.[274] All mine

267. *See* Thomas Chaize, *World Gold Production (2010),* GOLDSEEK.COM (May 13, 2010), http://news.goldseek.com/Dani/1273767071.php.

268. *See generally* NEV. ADMIN. CODE §§ 445A.433(1)(a), 445A.435.

269. *See generally* NEV. ADMIN. CODE §§ 445A.435(1), 445A.437.

270. *See* NEV. ADMIN. CODE § 445A.434(2),(3).

271. *See* NEV. ADMIN. CODE § 445.24358-.2437.

272. *See* NEV. ADMIN. CODE § 445A.433(1)(c).

273. *See* Paul E. Bailey et al., *Breaking New Ground: Legal Responses to the Challenges of Modern Mining,* SCITECH LAWYER, 8, 10 (2011).

274. IDAHO CODE § 47-1518 (2009).

operators are required to provide up $5,000,000 in financial assurances, and mines with cyanide facilities may be required to provide an even greater amount if the Idaho Board of Land Commissioners deems it necessary.[275] The purpose of the front-end bonding is to ensure that all approved back-end cyanide closure activities protect soil and groundwater at and surrounding the mine site.[276]

c. Complete Bans on Cyanide

Regulation, no matter how stringent or costly, still permits cyanide to be used in mining operations. The assumption with regulation is that the risk associated with cyanide use can be managed. But when the risk seems too great, or when fears associated with cyanide use are so intense that the scientific reality of cyanide harm to the environment becomes irrelevant, the response is often a flat ban on its use. A ban is a political admission that no amount of regulation can remove the extreme risk associated with the use of the banned substance. Several countries worldwide, as well as provinces within countries, at least one state in the United States, and several counties within an American state, have imposed flat bans on cyanide use in mining operations.[277] Countries with bans on cyanide include Costa Rica, which prohibited cyanide when it was thought, but not proven, that environmental degradation was occurring due to failure to control cyanide leaching facilities.[278]

In 2010, the EU considered but ultimately rejected a Resolution calling for a complete ban on all cyanide use.[279] Nevertheless, certain EU member countries have concluded that a total ban is warranted as the only means to protect against environ-

275. IDAHO CODE § 47-1512(d) (2009); IDAHO ADMIN. CODE r.02.121.02 (2009).

276. *See* IDAHO CODE § 47-1518 (2009).

277. *See U.S. Update,* MINES & CMTYS (Mar. 23, 2007), http://www. minesandcommunities.org//article.php?a=254.

278. In 2010, the president signed a decree completely banning all open pit mines and cyanide mineral leaching operations. *See Costa Rica's Elected President Bans New Gold Mines*, MINES & CMTYS. (May 20, 2010), http://www. minesandcommunities.org/article.php?a=10100.

279. *EU Commission Refuses Ban on Cyanide in Gold*, MINES & CMTYS. (July 17, 2010), http://www.minesandcommunities.org/article.php?a=10246.

mental harm resulting from accidental cyanide spills at mine sites.[280] EU countries adopting flat bans include Germany,[281] Hungary,[282] and the Czech Republic.[283]

In 1998, citizens of the state of Montana voiced their opposition to open-pit mining and cyanide leaching by adopting Citizen's Initiative I-137.[284] This statewide law prohibits the development of any new open-pit mining for gold or silver using cyanide heap leaching to process ore in the state of Montana after November 1998.[285] Because there are no economically viable alternatives to cyanide, the practical effect of I-137 was, and remains, that open-pit mining for gold in Montana is economically unfeasible.[286] I-137 does not apply retroactively because a grandfathering clause provides an exemption to the ban for any mine that was in operation with a valid permit on or before November 3, 1998.[287]

Because Montana contains enormous amounts of unrecovered gold,[288] there have been repeated attempts to repeal I-137. These proposals have either been vetoed by the governor or rejected by courts. In 2011, the governor of Montana vetoed Senate Bill 306, which would have amended I-137 to allow new open-pit gold and silver mines otherwise subject to the cyanide ban to instead process its ore at any cyanide leaching operation in existence prior to the enactment of I-137.[289] In 2005, the Montana

280. *See* SZILÁGYI, *supra* note 52, at 3.

281. *See id.* at 9 (explaining that Germany passed a decree in 2002 prohibiting mines from using cyanide leaching technologies).

282. *See id.* (explaining that Hungary established a total ban on all cyanide leaching technologies in 2009 by amending the Hungarian Mining Act No. 48/1993).

283. *See id.* (the Czech Republic imposed a general ban on cyanide leaching in any mine).

284. *See Seven Up Pete Venture*, 114 P.3d at 1013.

285. *See* MONT. CODE ANN. § 82-4-290(1) (1999).

286. *See* John Dwight Ingram, *All That's Gold May Not Glitter*, 18 UCLA J. ENVTL. L. & POL'Y 371 (2001).

287. *See* MONT. CODE ANN. § 82-4-290(2) (1999).

288. *See generally Gold in Montana*, THE GOLD HUNTER, http://goldhunter.webs.com/montanagold.htm (last visited Jan. 26, 2013).

289. S. 306, 62d Leg., Reg. Sess. (Mont. 2011) (vetoed).

Supreme Court upheld the constitutionality of I-137's cyanide leaching ban.[290]

In 2004, Summit County Colorado, along with several other counties in Colorado, enacted a land use ordinance banning cyanide and other acidic chemicals used in ore leaching processes within all zoning districts in the county.[291] The Colorado Mining Association (CMA) challenged the ordinance banning cyanide on the grounds that the ban was preempted by Colorado's Mined Land Reclamation Act (MLRA).[292] In 2009, the Colorado Supreme Court upheld CMA's challenge, finding that the MLRA impliedly preempted Summit County's cyanide ban because the statute specifically designated exclusive authority to the State Mined Land Reclamation board to regulate cyanide leaching operations.[293]

Despite the fact that no meaningful cyanide spills have ever occurred in Argentina, the fear and perceived environmental risks of cyanide loom large there. Several provinces with large gold deposits have banned the use of cyanide in mining. Argentine provinces with cyanide bans in effect include Chabut, Cordoba, La Pampa, Rio Negro, Mendoza, Tucumán, and San Luis.[294] By prohibiting the only economically feasible method of processing gold ore, these Argentine provinces have effectively proscribed gold mining in their jurisdiction.

A number of provinces in Argentina have repealed their bans on cyanide leaching, allowing for renewed minerals exploration and development. The specter of cyanide use has triggered heat-

290. *See Seven Up Pete Venture*, 114 P.3d 1009.

291. Colorado counties with cyanide leaching bans in effect at, or prior to, 2004 included Summit, Gunnison, Constilla, Gilpin, and Conejos Counties. *See* Leonardo G. Rodríguez & Francisco A. Macías, *To Cyanide or Not to Cyanide? Some Argentinean Provinces Banned Use of Cyanide in Mining Activities: Is this Prohibition Legal?*, 46 ROCKY MTN. MIN. L. INST. 237, 241 (2009).

292. *See* Colorado Mining Ass'n v. Board of Cnty. Comm'rs of Summit Cnty., 199 P.3d 718 (Colo. 2009).

293. *See id.* at 721.

294. *Argentina Province Bans Open-Pit Mines, Certain Chemicals*, MINES & CMTYS. (Oct. 7, 2008), http://www.minesandcommunities.org/article.php?a=8841&l=1; Rodríguez & Macías, *supra* note 291. In 2003, the providence of Chabut imposed a prohibition on open-pit mining for metallic minerals and cyanide leaching processes. *See* Law No. 5001, May 8, 2003 A.D.L.A. 1 (Arg.).

ed protests by angry and fearful local residents.[295] Retraction of the ban in the province of La Rioja allowed the Osisko Mining Corporation to enter into an agreement with the state mining company to begin feasibility studies for the Famatina project, a large gold mine proposal.[296] Despite the fact that Famatina is only an exploratory project, in which Osisko has yet to make any significant investments, the project has drawn heated opposition by local residents and environmental organizations, which has led to suspension of the protest.[297] These opponents claim that Famatina is a "mega-mine project" that, because of its reliance on cyanide, could damage the natural landscape.[298]

Similarly, in 2011 the Argentina province of Rio Negro repealed its law prohibiting cyanide leaching processes, and replaced it with new legislation permitting mines to process minerals with cyanide.[299] With Rio Negro's cyanide ban no longer in effect, the Pan American Silver Corporation has renewed efforts to develop the Calcatreu gold project, an open-pit gold mine, which, like most open-pit mines, is only economically feasible with cyanide leaching processes.[300] The environmental threat posed by cyanide has engendered fierce opposition to the Calcatreu project.[301]

The Patagonia area in Argentina cannot be mined—even without the provincial cyanide prohibition—due to a strict federal glacier-protection law, which prohibits mine projects in areas

295. *See Massive Protests Against Cyanide and Open Pit Mining in Bariloche, Argentina,* MINES & CMTYS. (Jan. 23, 2012).

296. *See* Frik Els, *Osisko Bogged Down at Same Argentina Project where Barrick came Unstuck*, MINING.COM (Jan. 30, 2012), http://www.mining.com/2012/01/30/osisko-bogged-down-at-same-argentina-project-where-barrick-came-unstuck/.

297. *See* Brent Patterson, *Canadian Mining Company's Plans in Argentina Stopped over Water Concerns*, COUNCIL CANADIANS (Feb. 7, 2012), http://canadians.org/blog/?p=13443.

298. *See Osisko Updates Status of Famatina Exploration*, OSISKO (Jan. 30, 2012), http://www.osisko.com/2012/01/osisko-updates-status-of-famatina-exploration-project/.

299. *See* Law No. 4738, Jan. 9, 2012, B.O. 1 (Arg.); *Massive Protests Against Cyanide and Open Pit Mining in Barilioche, Argentina*, MINES & CMTYS. (Jan. 23, 2012), http://www.minesandcommunities.org/article.php?a=11444.

300. *See* Els, *supra* note 296.

301. *Id.*

around glaciers in the Patagonia region.[302] Patagonia reflects the tension inherent in cyanide-based mining operations. On the one hand, booming commodity prices for gold and copper have made Argentina's large mineral reserves attractive prospects for new mine projects.[303] Emerging economies, like Argentina, see investments in mining as the key to a strong economic base.[304] On the other hand, the idea of cyanide being poured onto large heaps frightens environmental activists and certain indigenous people, who are afraid that cyanide, and its use in mines, will inevitably contaminate and spoil their countryside landscape and water supply.[305]

These bans on cyanide use, in America and elsewhere, seem to reflect a view about cyanide and the environment that is not consistent with either the scientific reality of cyanide (see Part III), or the history of how cyanide has been managed by mines (see Part IV (A) & (B)). What then causes governments to impose bans when they could instead simply regulate its use? These government bans seem to be responding to a popular or widely-held assumption about cyanide that appears to be far more powerful than science or ecological reality or an industry record of typically safe and uneventful cyanide use. What seems to be driving these fears about its use? Why is the perceived risk of cyanide so much greater than its actual risk?

V. OVER REGULATION IN THE FACE OF RISK AMPLIFICATION

A. Regulatory Fears Reflecting Perceived Risks of Cyanide

Anti-cyanide campaigns are active throughout the world, many of which have spurred cyanide related bans or strict regula-

302. *See id.*

303. *See* Jude Webber, *Power People! Mining Protest Spread to Argentina*, MINES & CMTYS. (Jan. 17, 2012), http://www.minesandcommunities/org/article.php?a=11444.

304. *See Pan American Silver Comments on Changes to Mining Legislation in Rio Negro, Argentina,* MINES & CMTYS. (Jan. 19, 2012), http://www.minesandcommunities.org/article.php?a=11444.

305. *See* Webber, *supra* note 303.

tion. After it experienced the consequences of being downstream from the Baia Mare, Romania spill, Hungary reacted quickly by completely banning the use of cyanide within its country.[306] The Romanian spill similarly caused the European Union to propose a resolution, founded on "good grounds," to ban cyanide throughout the EU.[307] The non-binding resolution encourages all EU nation-states to ban cyanide, and it undoubtedly influenced prohibitions on cyanide that were eventually adopted by several EU countries.[308]

Countries in the Western Hemisphere in Central and South America have experienced similar campaigns against cyanide. Argentina has not banned cyanide at the national level, but eight provinces have completely banned its use.[309] These draconian actions have occurred after events like those in San Juan Province, Argentina, where hundreds of citizens marched against mining operations and the use of cyanide there.[310] Their opposition was based on the claim that mines using cyanide violate a human right to clean water.[311] Cyanide also became a major topic of discussion between opposing presidential candidates in Peru, who sought to balance the growing fears about cyanide against the profitable mines that need cyanide to maintain mines tied directly to jobs creation in a struggling economy.[312]

306. *See* Stephanie Roth, *Great Victory Against Cyanide for Gold Mining*, ECOLOGIST (Jan. 8, 2010), http://www.theecologist.org/blogs_and_comments/commentors/other_comments/394395/great_victory_against_cyanide_for_gold_mining.html.

307. *See* Martin Banks, *Parliament Resolution on Cyanide Mining Branded 'Massively Harmful,'* THEPARLIAMENT.COM (May 4, 2010), http://www.theparliament.com/no_cache/latestnews/news-article/newsarticle/eu-parliamentresolution-on-cyanide-mining-branded-massively-harmful.

308. *See* Press Release, European Parliament, Mining Must Benefit all of Society and be Sustainable (May 30, 2012), *available at* http://www.europarl.europa.eu/intcoop/acp/2012_horsens/pdf/2012_communique_final_en.pdf.

309. *See* Shane Romig, *Argentina to Vet Mining Company Imports*, MARKETWATCH (May 28, 2012, 7:06 PM), http://www.marketwatch.com/story/argentina-to-vet-mining-company-imports-2012-05-28.

310. *See* Luis Angel Saavedra, *Mining Raises Concerns Over Water*, LATIN AM. PRESS (May 26, 2012), http://www.lapress.org/articles.asp?art=6634.

311. *See id.*

312. *See* Deborah Poole & Gerardo Rénique, *Peru: Humala Takes Off His Gloves*, N. AM. CONG. ON LATIN AM. (May 17, 2012), http://nacla.org/news/2012/5/17/peru-humala-takes-his-gloves.

Fears about cyanide and its perceived environmental risks certainly were prominent when Montana voters banned cyanide in mines by popular initiative, ending the ability of the Seven-Up Pete project to open a gold mine in the state.[313] In California, one environmental group, Environment California, hopes that a moratorium or ban, similar to the one million acres mining ban issued for the lands surrounding the Grand Canyon, be issued for the lands surrounding Yosemite National Park[314] because the organization believes the use of cyanide for mining claims located outside the park would still pose a risk to resources found within the Park.[315] In Alaska, several environmental groups are leading an anti-mine crusade against the proposed Pebble Mine, in part because of fears over cyanide risks.[316]

Such campaigns against cyanide contribute to the generally held fear that cyanide use carries a high risk of environmental damage, harm to wildlife, and possible threats to human health. Yet, the scientific, biological, and historical reality of cyanide use in mines suggests that cyanide does *not* pose a high risk of environmental harm. There is a disconnect between what is true and what is perceived.

B. Risk Amplification

An exaggerated and scientifically unjustified fear of cyanide is the result of an *amplification* of its true risk. Risk amplification occurs when humans conceive reality by simultaneously evaluating "the deliberative, logical, evidence-based 'rational system' and the 'experiential system,' which encodes . . . images,

313. *See* Dustin T. Till, *Supreme Court Declines to Review Montana Band on Cyanide Leach Mining*, MARTEN L. (Mar. 22, 2006), http://www.martenlaw.com/newsletter/20060322-leach-mining-ban.

314. *See* Susanne Rust, *California Gold Mining Threatens Yosemite National Park, Groups Say*, HUFFINGTON POST, Nov. 27, 2011, http://www.huffingtonpost.com/2011/09/27/california-gold-mining-threatensyosemite_n_983705.html.

315. *See id.*

316. *See* Joshua Rhett Miller, *$500B Alaskan Gold and Copper Mine in Up-Stream Battle with EPA, Salmon Advocates*, FOXNEWS.COM (July 24, 2012), http://www.foxnews.com/us/2012/07/24/proposed-pebble-mine-project-pits-big-coal-versus-sockeye-salmon/; *see also* Jeanne Devon, *The Time to Toss Pebble Mine is Now. Really.*, HUFFINGTON POST, July 19, 2012, http://www.huffingtonpost.com/akmuckraker/alaska-pebblemine_b_1687202.html.

metaphors, and narratives associated with feelings, with affect."[317] In other words, in the case of cyanide and mining, the very idea of cyanide triggers deeply disturbing images that are encoded within us. These images can then be exploited by those who oppose cyanide in mining operations to mount a campaign that eventually produces a ban on cyanide heap leaching operations, irrespective of scientific harm. This narrative of fear and risk amplification seems to have played out in Montana, when the Seven-Up Pete Joint Venture (the Venture) proposed to mine—with cyanide—lands encompassing the McDonald Project, containing millions of ounces of gold.

a. The Stigma of Cyanide, the Perception of Heightened Risk, and the Montana McDonald Project

In 1991, the Venture acquired property in the vicinity of Lincoln, Montana. According to feasibility studies, the lands encompassed by this property contain more than nine million ounces of gold and twenty million ounces of silver.[318] Approximately half of these minerals may be recovered profitably through open-pit extraction combined with cyanide leaching.[319] By 2013, gold was occasionally being priced at nearly $1,700/ounce, which means that the recoverable gold alone from the McDonald Project was (and is) worth well over seven billion dollars. The amount of gold in the McDonald Project site makes it one of the ten largest gold deposits in the world.[320] But the eventual mine (the McDonald Mine) would be located at the headwaters of Montana's most picturesque, famous, and beloved river—the Blackfoot, the same river featured in the Robert Redford movie and Norman Maclean novel, *A River Runs Through It*.

When a near-mythical river seemed threatened by a stigmatic, toxic poison, the result was a feeling of fear, which over-

317. *See* SLOVIC, *supra* note 17, at 79-80.

318. Seven Up Pete Venture v. Schweitzer, 523 F.3d 948, 951 (9th Cir. 2008).

319. *Id.*; Seven Up Pete Venture v. Montana, 114 P.3d 1009 (Mont. 2005).

320. Heather Abel, *Montana on the Edge: A Fight Over Gold Forces the Treasure State to Confront its Future*, HIGH COUNTRY NEWS, Dec. 22, 1997, http://www.hcn.org/issues/121/3851.

whelmed any evidenced-based rational system of decision making. Opponents of the McDonald Mine focused on the poison that would be used to leach out the gold, and argued that the risks were too high. As one Montana resident succinctly posed the issue: "But you need to realize the difference between a pond of . . . cyanide and a pond of cow shit. I'll take my chances with a pond of cow shit."[321] Other mine opponents were equally graphic and to the point, stating simply, and loudly, that "[c]yanide leach gold mines are the poison that threatens Montana's surface and ground water."[322]

In November 1998, pleas from the mining industry to listen to assurances about the science of cyanide fell on deaf ears: Citizen ballot initiative I-137 was passed, making Montana the first state to flatly prohibit open-pit mining using cyanide heap leaching.[323] Because there are no recovery processes other than open-pit mining and cyanide leaching that can facilitate the economical production of gold from the McDonald Project, the Venture ceased all further operations.[324] Industry advocates concluded that I-137 passed for two reasons:

> One was fear. Environmentalists capitalized on dire connotations of cyanide, which gained infamy as the agent of death in the 1978 Jonestown massacre in Guyana and in the macabre 1982 contaminations of Tylenol with substance in Chicago . . . . The other reason . . . was the inability of the industry to counter the environmentalists' campaign.[325]

These two reasons encapsulate the problem that lawmakers confront in addressing the issue of how vigorously to regulate cyanide in mining operations. The bare idea of "cyanide" seems to conjure up images of an inevitable "agent of death," while rational, fact-and-science based arguments that conclude otherwise suffer from an "inability . . . to counter . . . the campaign" that labels

321. *Id.*

322. Sherry Devlin, *Debate Over Cyanide Initiative Turns Sour*, THE MISSOULIAN (Oct. 13, 1998), http://missoulian.com/article_551dac69-129a-5d39-a96b-bae3f712f63b.html.

323. MONT. CODE ANN. § 82-4-390 (1998).

324. Seven Up Pete Venture v. Schweitzer, 523 F.3d 948, 951 (9th Cir. 2008).

325. Brandon, *supra* note 221.

cyanide as a deadly, toxic poison wherever it is used.[326] Indeed, in 2004, an initiative sponsored by the Venture's owner, Canyon Resources, to overturn the 1998 ban was soundly defeated at the polls because of inchoate fears about the health and environmental risks of cyanide.[327] The Montana Conservation Voters argued that cyanide-leach mining "causes both ground and surface waters to be poisoned, posing a threat to public health, trout, and other aquatic life."[328] Other arguments against the initiative echoed these fears. One rancher was quoted as saying, "I studied cyanide leach open-pit mining and its impact on surface and groundwater. I concluded that the downstream threat to public health is very real. It does not make sense to keep doing something that *always fails*."[329] If lawmakers are convinced, despite data to the contrary, that mining activities using cyanide "always fail" to protect the environment, then one should not be surprised that the resulting regulatory response is a complete ban.

b. The Problem of Intuitive Toxicology, Affect Heuristics, Stigmas, and the Social Amplification of Risk

The saga of the McDonald Project illustrates a phenomenon that frequently occurs when law and policymakers are confronted with the task of determining the level of regulation needed for a chemical that conjures up disturbing images in the minds of the public. The Venture's owners faced opposition to the McDonald Project, because it involved the chemical cyanide, which was to be used as a leachate in the proposed Seven Up Pete open-pit mining project.[330] What the owners of the Venture experienced at the hands of Montana voters was a bottom-up regulatory decision to

326. See Devlin, *supra* note 322.

327. *Montana Miners and Merchants Compliance, Measure I-147*, BALLOTPEDIA (2004), http://ballotpedia.org/wiki/index.php/Montana_Miners_and_Merchants_Compliance,_Measure_I-147_%282004%29.

328. *Id.*

329. *2004 Voter Information Pamphlet*, OFFICE OF THE MONT. SEC'Y OF STATE 28 (2004), http://sos.mt.gov/elections/archives/2000s/2004/VIP2004.pdf (emphasis added).

330. *See* Seven Up Pete Venture v. Schweitzer, 523 F.3d 948 (9th Cir. 2008).

eliminate *all* risk by banning the troublesome chemical.[331] Federal officials have experienced a similar regulatory choice when they have considered the level of regulation needed in setting top-down drinking water limits for an equally disturbing chemical—arsenic.[332] In both the Montana example involving whether to permit the use of cyanide in mining, and the federal example involving regulation of arsenic in drinking water, legal decisions were not simply data-and-science based, but instead were caught up in another reality that greatly influenced the legal outcome. That other reality—risk amplification—should not be ignored when lawmakers consider how to respond to the risks of adding certain chemicals to the natural or human environment.

As exemplified by the passage of I-137 in Montana when cyanide use was contemplated at the McDonald Mine site, the perceived risk of the chemical was amplified by humans who ignored rational factors including: 1) the amount of cyanide spilled; 2) the physical properties of the environment that absorb the spilled cyanide; and 3) the chemical composition of cyanide, which permits it to degrade quickly to a harmless substance.[333] Instead, risk reality was considered in tandem with emotional factors of the human experiential system. The word *cyanide* evoked a stronger reaction from the experiential system than the rational system of cognitive evaluation. When the chemical cyanide was to be used in heap leaching, what seemed to be evoked were images of Nazi gas death chambers, the Jonestown massacre in Guyana, warning signs on poisons embodying skulls and cross bones and the words "cyanide present," and the ecological aftermath of catastrophic mining disasters.[334] These shocking images seem to strike the human memory more effectively, and more powerfully, than pure facts.[335]

331. *See id.*
332. *See* Sunstein, *supra* note 17.
333. *See Montana Cyanide Process Open Pit Mining Prohibition, Initiative*, BALLOTPEDIA, http://ballotpedia.org/wiki/index.php/Montana_Cyanide_Process_Open_Pit_Mining_Prohibition, Initiative_I-137_%281998%29 (last modified Nov. 19, 2011).
334. *See generally* CYANIDE SPILL, *supra* note 195; *see* Brandon, *supra* note 221.
335. *See* SLOVIC, *supra* note 17.

Emotions stirred by images seem to remain with us, while we grow numb to rational reactions produced by numbers, figures, and calculations.[336] Images are linked to cyanide by the human brain and are either classified as positive or negative feelings. Since images associated with cyanide are dramatically disturbing, when the brain has to make a decision linked to cyanide, it is often negative, even if the data is rationally positive.[337]

In the case of arsenic, federal regulatory attempts to establish a "rule" for acceptable levels of arsenic in drinking were similarly met with a "public outcry" that reflected both concern and cynicism.[338] Commentators reviewing this public outcry were puzzled about the hysteria and public uncertainty about what the appropriate levels of arsenic should be: "With respect to arsenic, the underlying issues are highly technical, and very few people are expert on the risks posed by exposure to low levels of arsenic. What accounts for the public outcry? . . . [T]he reason is simple: *Arsenic* was involved . . . ."[339]

In the case of cyanide and mining, and arsenic in drinking water, the mere idea of a deadly poison entering either the natural or human environment seems to create a visceral response that is universally alarmist and negative. The actual facts about the toxic nature of these substances are too often ignored. For example, the anger in Montana about the proposed McDonald Project did not take into account the fact that if an organism is exposed to cyanide in levels that are not actually lethal, most of these organisms, even aquatic life, can metabolize the cyanide into less toxic forms.[340] Similarly, the "public outcry" about the proposed arsenic rule did not carefully consider that the risk of arsenic poisoning of humans is not linearly related to arsenic concentrations, because the human body can metabolize arsenic at low, sub-lethal levels.[341]

336. *Id.* at 285.

337. *See generally* Roger G. Noll & James E. Krier, *Some Implications of Cognitive Psychology for Risk Regulation*, 19 J. LEGAL STUD. 747 (1990).

338. Sunstein, *supra* note 17, at 2261.

339. *Id.* (emphasis added).

340. *See* Griffiths et al., *supra* note 188.

341. JASON K. BURNETT & ROBERT W. HAHN, EPA'S ARSENIC RULE: THE BENEFITS OF THE STANDARD DO NOT JUSTIFY THE COSTS, AMERICAN ENTERPRISE INSTITUTE – BROOKINGS JOINT CENTER FOR REGULATORY STUDIES (2001), *available*

Instead of calmly and deliberately integrating facts about risk, an ordinary person who may be affected by the poison engages in a form of "intuitive toxicology."[342] Such "intuitive toxicologists" then arrive at a simple set of rules for thinking about environmental risks.[343] In the case of cyanide, one of those simple rules, reflected in the Montana I-137 vote, is a belief that poisonous substances are environmentally dangerous and should therefore be banned. In the case of arsenic, the rule was that substances that cause death to humans are unsafe and should be banned. Intuitive toxicology does not make room for varying degrees of regulation; flat bans are more simple, the most risk averse, and safer.[344]

A component of intuitive toxicology is the tendency of ordinary people to rely on what some commentators call the "affect heuristic," where automatic mental shortcuts affect judgments about risks.[345] Rather than engage in a careful inquiry of likely consequences, based on fact, data, and science, an affect heuristic governs feelings, which become very risk averse.[346] The affect heuristic then permits persons to complete a simple syllogism about substances like cyanide and arsenic:

- Poisons are deadly
- Poisons should not be in the natural environment or in our bodies
- Poisons should be banned because we do not want to risk the harm they produce
- Cyanide and arsenic are poisons
- Cyanide and arsenic should be banned

When cyanide is used in mining, and arsenic is in drinking water, risk perceptions are also influenced by the fact that there

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at http://regulation2point0.org/wp-content/uploads/downloads/2010/04/phppu.pdf.

342. Sunstein, *supra* note 17 at 2257.

343. *Id.* at 2262; SLOVIC, *supra* note 17, at 413-27.

344. SLOVIC, *supra* note 17, at 285-314.

345. Sunstein, *supra* note 17 at 2262.

346. *Id.*; SLOVIC, *supra* note 17, at 413-17; John S. Applegate, *A Beginning and Not an End in Itself: The Role of Risk Assessment in Environmental Decision-Making*, 63 U. CIN. L. REV. 1643, 1659 (1995).

is a *stigma* associated with it.[347] Stigma occurs when a substance is identified by the public as dangerous and subject to avoidance given its connection to health or environmental risks.[348] When a substance, like cyanide or arsenic, is stigmatized, this fact conflates to negative cognitions about it, including high perceived risk, which in turn produce changes in public attitudes about that substance.[349] When there is a stigma attached to a substance like cyanide or arsenic, the public fears it, the public wishes to avoid it, and the public assumes that there is high risk associated with its use.[350] There is then a gap between the true, scientific risk associated with cyanide use, and the exaggerated risk reflected in regulatory bans.

A combination of intuitive toxicology, affect heuristics, and stigmas create a regulatory reality that has been termed the Social Amplification of Risk Framework (SARF).[351] This Framework describes the disconnect that occurs when events or specific hazards that experts believe are relatively low in risk elicit instead substantial negative focus and attention, greatly amplifying the perceived risk of the hazard.[352] Once an event occurs, such as a cyanide spill, or a specific hazard is present, such as arsenic, the social entities that label and culture the event, and each individual's filtering and decoding process, create ripple effects that result in the amplification of risk. This social amplification process is *as important* as the direct physical consequences of the event.[353] In the case of cyanide, highly influencing events, such as the cyanide spills in Baia Mare, Romania, and the Summitville Mine in Colorado, or the hyper-publicized fears about the McDonald Project contaminating the Blackfoot River, easily fall within the SARF. These events, or threatened events, create opportunity for social stations like government entities, environmental activist groups, and societal institutions to ramp up an

347. SLOVIC, *supra* note 17, at 215-17.

348. R. Gregory et al., *Technological Stigma*, 83 AM. SCIENTIST 220, 220 (1995).

349. *See id.*

350. Paul Slovic, *Perception of Risk*, 236 SCI. 280 (1987) (Arsenic is another chemical that suffers from risk amplification); *See* Sunstein, *supra* note 17.

351. *See* SLOVIC, *supra* note 17.

352. *Id.* at 317-22.

353. *Id.* at 321.

individual's perception of the risk of cyanide. The result is that cyanide is often thought to produce far more risk of environmental harm than is warranted by scientific and ecological reality.

c. Risk Amplification and Over-Regulation

Human behavior and thought is made largely of images, where a lifetime of learning marks these images with positive and negative feelings. A negative feeling "sounds an alarm when linked to a future outcome."[354] Such an alarm often has a more pronounced effect on risk perception than logical cognitive evaluations of risks and benefits.[355] If a policy maker or a regulator or a voter contemplating a response to a proposed mine has experienced an emotional reaction to the negative environmental effects seemingly associated with cyanide, no amount of rational positive data about cyanide will dislodge the "negativity" connected to cyanide. This negativity helps to amplify risk.

When SARF is driving policy, intense emotional reactions to particular incidents (e.g., highly publicized mine spills involving cyanide) become so dominant that both voters and policymakers make mistakes in thinking about the seriousness of risks.[356] These mistakes can lead to "large blunders" when regulatory policy reflects a heightened averseness to risk which is not grounded in fact or science.[357] The tendency is to focus on the severity of the possible consequence of a cyanide spill rather than on the relative likelihood of that spill ever occurring.

The end result may be over-regulation, often in the form of flat bans. Such over-regulation is inefficient; it depresses output by artificially raising both the cost of overregulated goods (e.g., gold), and the opportunity cost of economic benefits lost (e.g., employment in mines) by the ban. In such cases, the cost of achiev-

354. SLOVIC, *supra* note 17.
355. *See* George Loewenstein et al., *Risk as Feelings*, 127 PSYCHOL. BULL. 267 (2001).
356. Sunstein, *supra* note 17, at 2266.
357. *Id.* at 2257.

ing a cleaner environment may outweigh the social benefits of environmental protection.[358]

The problems of SARF, including its reliance on intuitive toxicology, mental shortcuts and affect heuristics, and its overreaction to stigmatized substances, can be moderated by more regulatory reliance on other default decisional principles, such as cost/benefit analysis (CBA) or risk assessment. CBA helps to insure that when government acts, it does so with some understanding of the likely consequences of that action.[359] Risk assessment encourages and facilitates regulatory action that is useful for organizing relevant information, and making policy decisions on the basis of the likelihood and severity of the actual threat rather than the perceived threat.[360] Since flat bans on cyanide use in mining seems to be the result of both SARF and exaggerated fears about risk,[361] it will be useful to perform a risk assessment with respect to this stigmatized chemical. Any such risk assessment should encompass not only the normal variables of probability and degree of environmental harm; it should also reflect the near-certainty that SARF will accompany virtually any proposed use of cyanide in a mine.

VI. A MORE REALISTIC RISK ASSESSMENT FOR CYANIDE USE

More than 90% of gold recovered worldwide relies upon the use of cyanide.[362] Cyanide is also an effective way of leaching out silver and copper.[363] In several of these countries, there have been cyanide spills or leaks, which have resulted in varying environmental consequences.[364] These cyanide-mining accidents

358. John S. Applegate, *The Perils of Unreasonable Risk: Information, Regulatory Policy, and Toxic Substances Control*, 91 COLUM. L. REV. 261, 265 (1991); Sunstein, *supra* note 17, at 2256, 2263-65.

359. Sunstein, *supra* note 17, at 2263.

360. *See generally* STEPHEN BREYER, BREAKING THE VICIOUS CIRCLE: TOWARD EFFECTIVE RISK REGULATION (1993); Applegate, *supra* note 346, at 1657-58.

361. *See supra* Part IV.

362. *See* Mudder & Botz, *supra* note 26, at 62.

363. *See id.*

364. Abraham Kumah, *Sustainability and Gold-Mining in the Developing World*, 14 J. CLEANER PRODUCTION 315 (2006).

have led to strict bans on, or robust regulation of, cyanide use in various countries and in American states.[365] Alternatively, state and foreign governments have responded to the perceived threat of cyanide by requiring mining operators to pay, up front, for mitigation damages should an accident occur involving cyanide.[366] In America, such regulations of cyanide, and of mining operations generally, have made mining so burdensome that as of 2012 the United States was tied for last place in the time it takes to permit a new mine—seven to ten years on average.[367]

These strict regulatory responses reflect a real fear of potential threats to humans, and of perceived dangers to the natural environment, when cyanide is contemplated in mining operations to extract gold and precious metals. In order to determine the true risk that cyanide-dependent mining operations pose to the environment, it will be useful to perform a qualitative risk assessment that incorporates the risk amplification that is often associated with cyanide.

A. Components of an Environmental Risk Assessment

Instead of simply responding to fears about cyanide based on speculation, rhetoric, and near panic, a more reflective and educated response would seek to consider the probability of the true dangers of cyanide in mining operations, and the most appropriate response to this risk. A combination *risk assessment* and *risk acceptance* analysis can be used to measure, (1) the likelihood or probability of a cyanide spill occurring, (2) the gravity of harm should one occur, and, (3) the level of risk that would be deemed acceptable.[368] Countries, governments, and American states and counties considering a regulatory response to cyanide use in mines, may then be able to assess the real (as contrasted with the perceived) threat of cyanide to the surrounding environment.

365. *See id.*
366. *See supra* Part IIV.C.
367. Daniel McGroarty, *America's Growing Mineral Deficit*, WALL ST. J., Jan. 31, 2013, at A15.
368. *See generally* LOGSDON ET AL., *supra* note 19; NAT'L RES. COUNCIL, RISK ASSESSMENT IN THE FEDERAL GOVERNMENT: MANAGING THE PROCESS 18-28 (1983).

A risk assessment may also apply factors that compare the costs of preventing cyanide spills, through regulations like bans, to the cost of mitigating damages should they occur.[369] These risk assessment variables, which should also take into account the many uncertainties that arise in performing such an analysis, may be weighed by local, state, or national governments to determine what rules and regulations, if any, to adopt in response to cyanide use in mines, known as "risk management."[370] This more systematic and thoughtful analysis of the cyanide "problem" for mining operations seems preferable to a response driven by misinformation, inchoate fears, alarmist propaganda, and false assumptions.

When establishing an acceptable level of risk for human exposure to a chemical or environmental hazard, policy makers often engage in a *quantitative* risk assessment.[371] A 1983 publication of the National Academy of Sciences, *Risk Assessment in the Federal Government: Managing the Process*, sets out the form of risk assessment that has come to dominate environmental regulation of human health hazards.[372] There are four major steps associated with a quantitative risk assessment: Hazard identification, dose-response assessment, exposure assessment, and risk characterization.[373] These steps help regulatory agencies in determining whether a chemical agent affects human health, and if so, how much exposure is necessary before there is an adverse human health effect.[374]

Quantitative methods are a more narrow analysis used to identify likelihoods as frequencies or probabilities, and identify and report risk in terms of scale or magnitude, use specific values, such as number of fatalities or number of individuals within a species lost.[375] On the other hand, qualitative methods use de-

369. NAT'L RES. COUNCIL, *supra* note 368, at 18-28.
370. *See id.* at 18-19.
371. *See id.*
372. *See id.*
373. *See id.*
374. *See id.*
375. *See* AUSTL. DEP'T OF RES., ENERGY & TOURISM, RISK ASSESSMENT AND MANAGEMENT (2008), *available at* http://www.ret.gov.au/resources/Documents/LPSDP/LPSDP-RiskHandbook.pdf.

scriptive terms to categorize risks (i.e. "high risk," "insignificant risk," "likely to occur," "rare," etc.) to identify consequences, the likelihood of events, and the resultant risk.[376] Qualitative risk assessment methods identify broad consequences and/or likelihoods, and provide a general understanding of comparative risk between potential risk events,[377] which makes it more suitable for including the "perception" variable, that can amplify the risk, even if unwarranted. The information gathered during the assessment is then evaluated using pre-determined risk acceptance thresholds to prioritize the risks.[378]

As discussed in Part III, when there have been significant spills of cyanide containing effluent, the damage was primarily limited to ecological damage opposed to human deaths, quantitative risk assessment may not be helpful because it requires a more narrow analysis.[379] Instead, policy makers should engage in a different class of risk assessment, which might be termed a "qualitative" risk assessment. Often, qualitative information about environmental exposures to chemicals is more useful and understandable than quantitative estimates of risk.[380] The United States Environmental Protection Agency (EPA) engages in this type of risk assessment when it characterizes the nature and magnitude of risks to "ecological receptors" (e.g., birds fish, wildlife) from chemical contaminants and "stressors" (like cyanide), that may be present in the environment.[381] Basically, the risk assessor evaluates the frequency and likelihood of environmental exposures that may occur as a consequence of contact with the chemical stressor, the inherent toxicity of the chemical stressor, the ease or difficulty of preventing the exposure in the first place,

376. *See id.*

377. *Id.* at 49.

378. *Id.* at 51.

379. *See supra* Part III.

380. THE PRESIDENTIAL/CONG. COMM'N ON RISK ASSESSMENT AND RISK MGMT., RISK ASSESSMENT AND RISK MANAGEMENT IN REGULATORY DECISION-MAKING, FINAL REPORT VOLUME 2, 85-88 (1997), *available at* http://www.riskworld.com/Nreports/1997/risk-rpt/volume2/pdf/v2epa.PDF.

381. *See generally* EPA, GUIDANCE ON CUMULATIVE RISK ASSESSMENT: PART 1 PLANNING AND SCOPING (1997), *available at* http://www.epa.gov/spc/pdfs/cumrisk2.pdf

and the uncertainties in the data for risk assessment calculations.[382]

Risk managers and those who make regulatory policy may then use this information to decide how to protect the environment from such stressors. The selection of an appropriate regulatory response necessarily requires the use of value judgments on such issues as the acceptability of risk and the reasonableness of the costs of control. The process of evaluating alternative regulatory actions and selecting among them, after completion of a risk assessment, is usually termed risk management.[383] In practice, the distinction between risk assessment and risk management is blurred. In part, this blurring results because it is impracticable to easily separate science from policy when one is seeking to make a risk-based decision.[384] Also, as the National Research Council has cautioned, one should not assume a "strict separation . . . between the conceptually distinct aspects of risk assessment and risk management because nonscientific considerations . . . are relevant to risk assessment."[385] One such "nonscientific consideration" that should be taken into account in any assessment of risk should be certain social values that affect both popular and policy judgment.[386] If a risk assessment for cyanide in mining is to be performed, one such social value that should not be ignored is the prevalence of SARF.

A risk assessment for environmental risk, as contrasted with a "quantitative" risk assessment for human exposure to a chemi-

382. *See generally* EPA, *Basic Information*, http://epa.gov/riskassessment /basicinformation.htm (last visited Oct. 22, 2012).

383. *See* BREYER, *supra* note 360, at 9 (risk regulation "has two basic parts, a technical part, called 'risk assessment,' designed to measure the risk associated with the substance, and the more policy-oriented part, called 'risk management'").

384. Shelia Jasanoff, *Science, Politics, and the Regulation of Expertise at EPA*, 7 OSIRIS 194, 209 (1992).

385. Cary Coglianese, *Shifting Sands: The Limits of Science in Setting Risk Standards*, 152 U. PA. L. REV. 1255, 1280 (2004); NAT'L RES. COUNCIL, UNDERSTANDING RISK: INFORMING DECISIONS IN A DEMOCRATIC SOCIETY 34 (1996).

386. Howard Latin, *Good Science, Bad Regulation, and Toxic Risk Assessment*, 5 YALE J. ON REG. 89, 90 (1988) ("social policy considerations must play as prominent a role in the choice of risk estimates [i.e., risk assessment] as in the ultimate determination of which predicted risks should be deemed unacceptable....").

cal, will likely focus on the two primary components of risk—(1) the negative or harmful environmental/ecological impacts of the risk (i.e., the ecocentric "loss" that follows from the adverse consequences of environmental exposure to a toxic agent), and (2) its probability of occurring (i.e., the likelihood that environmental harm will occur from the risk).[387] In addition, any attempt to measure the risk of using a toxic substance like cyanide should also factor into that calculation the considerable *uncertainties* that are inherent in the scientific data, as well as the very human tendency to ignore this data if the risky substance is stigmatized.[388] Finally, if risk managers do not simply wish to eliminate all risks, such as by a flat ban, and instead wish to opt for a policy that instead avoids unacceptable risks, then it is important to include in a risk assessment the cost and effectiveness of differing degrees of risk *mitigation* and *management*.[389]

If one were to shorthand these four variables into a non-quantitative, more qualitative environmental risk assessment formula, it might look like this:

R (acceptable risk) = p(L) + u – m

The probability ***(p)*** generally looks to the likelihood of an adverse effect occurring. With respect to a cyanide risk assessment, ***p*** would measure the probability of cyanide use in mining adversely affecting the physical and natural environment. The loss ***(L)*** variable measures the gravity or seriousness of the negative consequences of the environmental loss, should an accident occur involving cyanide in a mining setting. In a cyanide risk assessment, ***L*** is influenced by how cyanide is released into the environment and the impact it then has on wildlife, ecological, and environmental assets.

387. WILLIAM W. LOWRANCE, OF ACCEPTABLE RISK 75-76 (1976) ("Determining safety, then, involves two extremely different kinds of activities . . . . Measuring risk - - measuring the probability and severity of harm . . . .").

388. Alyson C. Flournoy, *Legislating Inaction: Asking the Wrong Questions in Protective Environmental Decisionmaking*, 15 HARV. ENVTL. L. REV. 327, 333, 387 (1991).

389. Coglianese, *supra* note 385, at 1326-32.

The uncertainty variable ***(u)*** takes into account the unknowns and educated, but not-certain, guesses that are necessarily part of such an analysis. For example, there remain scientific uncertainties concerning the chronic, long-term effects of a cyanide release. Another uncertainty involves the degree of "risk amplification" that will occur in the case of cyanide. This level of uncertainty *adds* to the risk **(R)**. The risk mitigation variable ***(m)*** addresses the effects of risk avoidance techniques imposed before-the-fact, as well as the remediation of negative consequences after-the-fact of an accident involving cyanide. The mitigation variable **(m)** *decreases* the risk **(R)**. The mitigation variable for cyanide in mining would include an emergency response plan, encompassing downstream notification, containment measures, treatment techniques, and long-term monitoring. It is also important that advocates of the activity perceived to be risky (i.e., using cyanide), to defuse the false "amplification" of risk that often exists.

B. The Probability of a Cyanide Spill Causing Injury to Environmental Assets (p)

To determine the likelihood of a cyanide spill from a mining operation producing damage to or pollution of the surrounding environment, it is important to first look at the levels of cyanide exposure that may be harmful to the environment. As noted above, in Part III, the level of cyanide that causes harm varies with the type of organism that comes into contact with it. Aquatic life in particular is often the most susceptible to cyanide spills.[390] While birds and mammals may also be affected, usually as a result of contact with the contaminated water, non-aquatic species are usually not the victims of cyanide releases.[391]

The concentration of the cyanide in a spill will vary and have different environmental effects depending on the size and extent of the water body affected. Studies have shown that cyanide spills that have a "meaningful" environmental impact are those exceedingly rare occurrences where thousands of cubic meters of

390. *See* CYANIDE HAZARDS TO FISH, WILDLIFE, AND INVERTEBRATES, *supra* note 157.

391. *See id.*; CYANIDE IN MINING, *supra* note 92.

cyanide-laced rock, or several thousand liters of cyanide-contaminated water, have been released. Spills of this proportion are more likely to have substantial negative effects on the environment, causing the death of many different organisms, or perhaps adversely affecting a significant percentage of one or more species.[392] Of course, the term "meaningful" is subjective. Some may consider even spills causing little or no environmental harm to be meaningful, because any spill containing cyanide still exposes the surrounding environment to a known toxin, even if the actual potential threat to the environmental community is marginal.

The degree of risk entails more than an assessment of likelihood of harm if cyanide is released. A "likelihood" analysis also considers the probability of a cyanide accident occurring at a mine site that might affect the environment. Such an analysis incorporates both the total number of cyanide spills that have occurred, as well as those that have had significant environmental impacts. One such analysis found that of sixty-seven environmental incidents in the mining industry that occurred globally in the past fifty years, only twelve were caused by cyanide spills.[393] This risk level equates to approximately three incidents caused by cyanide per decade.[394] However, other investigations point to thirty-four cyanide incidents since 1997, equating to approximately three incidents per year.[395]

The difference in these figures is a result of the nature of the particular spills included in each analysis. The lower estimate—three incidents per decade—is limited to much larger, more "meaningful spills," like the one that occurred in Romania in 2000.[396] That dramatic event involved the release of 100,000 cubic meters of cyanide-bearing wastewaters into the Danube River system, causing massive fish kills.[397] The higher number—three

392. *See* discussion *supra* Part I.
393. Hadfield, *supra* note 205, at 56.
394. *Id.*
395. *Cyanide Incidences*, RAINFOREST INFO. CTR., http://www.rainforestinfo.org.au/gold/spills.htm (last visited Oct. 22, 2012) [hereinafter *Cyanide Incidences*].
396. *See* Hadfield, *supra* note 205, at 56.
397. *Cyanide Incidences*, *supra* note 395.

incidents per year—includes *de minimus* spills having little or no effect on the environment, like one that occurred in New Zealand in 2004.[398] That incident in New Zealand involved a spill of only two 180-litre drums of cyanide, which required the temporary evacuation of thirty-four people, where there were no long-lasting environmental consequences.[399]

Collectively, these reports may be used to calculate the likelihood of a cyanide spill causing environmental harm. All the studies suggest that there are about three cyanide spills per decade, world-wide, that cause *substantial* environmental harm, while both *de minimus* and substantial spills amount to a frequency of about thirty spills per decade. Assuming the accuracy of these reports, if there are approximately thirty cyanide spills per decade, and three of these spills cause substantial environmental harm, it may be calculated that approximately one out of every ten cyanide spills is of meaningful proportions, causing substantial harm to the environment.

While such analyses are somewhat subjective and rely upon accurate reporting of cyanide spills and their effects, they provide a starting point for determining (1) the relative likelihood of a cyanide spill, and (2) the likelihood that any given spill may cause meaningful harm to the environment. Three substantial cyanide spills per decade is a number that suggests that cyanide spills producing harm to the natural environment are not common, and in fact are infrequent and rare. In light of the number of mines world-wide using cyanide,[400] one could say that the likelihood of a serious and meaningful cyanide spill from any given mine is extremely *low*. These variables may then be used in the next step of the risk assessment, which is to analyze the gravity of harm that would be caused by a cyanide spill, should one occur.

C. The Risk of Ecological Loss Using Cyanide in a Mining Operation (L)

The loss **(L)** component of a risk assessment measures the harm to the environment, or the gravity of the resulting loss of

398. *See* Hadfield, *supra* note 205, at 56.
399. *Cyanide Incidences*, *supra* note 395.
400. *See* Mudder & Botz, *supra* note 26.

environmental assets, should it occur. The ecological effect of a cyanide spill is influenced not only by whether it is *de minimus* or meaningful, but also by *how* it is released, what *form* the cyanide is in when it is exposed to the environment, and *where* it is released.

a. How it is Released

A *de minimus* spill will have little or no negative impact on ecosystems, water, or the natural environment. There is virtually no adverse environmental effect then because the amount that is released is not substantial enough to create harmful levels of cyanide to most organisms.[401] Cyanide is biodegradable and when it is released to water bodies, it may quickly transform to a substance that is less toxic. It is only when the quantity of cyanide in the spill overwhelms this important transformative quality that the spill becomes a meaningful incident. A "meaningful spill" of several thousand liters of cyanide at one time might very well create concentrations of cyanide in the water high enough to cause a substantial fish kill and other environmental damage to the aquatic environment downstream of the spill location.[402] The cyanide release near Baia Mare, Romania in 2000 which exemplifies what is considered a "meaningful spill," swept down the Danube River system and eventually entered the Black Sea.[403] These kinds of catastrophic spills, however, are exceptionally rare; for example, even the waterway affected by the huge Baia Mare Spill eventually recovered, in part because of inflow of unaffected water and in part because of the temporary nature of cyanide toxicity.[404]

The primary methods of cyanide release in the gold-mining industry include:[405]

1. cyanide released to watercourses or soil from heap mounds or heap leach ponds as a result of loss of con-

401. *Supra* Part III.E.
402. *See* Balkau, *supra* note 213 (reporting 1,000 tons of fish killed).
403. *See generally* CYANIDE SPILL, *supra* note 195.
404. *See generally id.*
405. *See supra* discussion at pp. 31-33.

tainment (e.g., after floods or if liners are not impermeable);
2. cyanide trapped in gold mine tailings releasing toxic metals into groundwater and surface water systems;
3. cyanide spills during transportation of the cyanide to the mine site.

The last of these routes to the environment—spills during transportation—involves both solid cyanide, such as sodium cyanide, and liquid cyanide.[406] If solid cyanide is deposited or spilled on the earth, there is little danger so long as the pellets are kept dry and are quickly removed after the release.[407] Liquid spills on land during transportation may be effectively remedied by being treated with oxidizing agents.[408]

While cyanide exposure can be fatal to humans, acute poisoning is unheard of when cyanide is used in mining operations.[409] So the loss **(L)** resulting from a cyanide release affects the natural environment and its living organisms, not humans. Organisms affected include aquatic species, birds, and some small terrestrial animals. The main exposure path to a cyanide spill for most terrestrial animals and birds is through consumption of surface water although concurrent exposure through inhalation and skin absorption is also possible.[410] Animals may also take cyanide into their bodies in tailings slurry or sediments during foraging while consuming carcasses or preening feathers.[411] However, animal deaths are not the usual outcome unless the cyanide is in both high concentrations and in sufficient dosage.[412] That said, dosage duration is particularly important and is one factor that affects the differences in susceptibility to cyanide by terrestrial, avian, and aquatic organisms. For example, a terrestrial organism may ingest a small, non-lethal amount of cyanide (i.e. a dos-

406. NEEDHAM, *supra* note 15, at 39.
407. *Id.*
408. *Id.*
409. *Id.* at 1.
410. *Id*. at 6.
411. *Id.*
412. *See supr*a Part III.C-E (for discussion on variances in dosage required for fatal effects); *see Environmental and Health Effects of Cyanide*, INT'L CYANIDE MGMT. CODE FOR THE GOLD MINING INDUS., http://www.cyanidecode.org/cyanide_environmental.php,

age from an affected water body) and then metabolize the cyanide to less toxic thiocyanate, but an aquatic organism, like a fish, is continually exposed until the cyanide is flushed from the system or diluted.[413]

Unlike many spills that occur during transportation, spills into surface waters are more difficult to treat due to rapid dispersal of the cyanide.[414] Treatment of waters using oxidizing agents may further damage the water body. Typically, little can be done to surface waters invaded by a cyanide solution except to dilute and disperse the spill, and to encourage natural degradation.[415] While rapid detoxification can occur naturally in the environment, large spills into surface waters remain one of the main causes of massive fish kills.[416] Cyanide may also contaminate both surface and groundwater after a loss of containment from heap leach ponds and gold mine tailings releases.[417] While cyanide may detoxify quickly in surface water, it can persist in groundwater for extended periods of time because of slow rates of oxidation, biodegradation, and volatilization occuring under the earth.[418] By contrast, cyanide-polluted surface water that is exposed to air, ozone, and sunlight will lose its toxic effects fairly quickly.

b. The "Form" of the Cyanide When Released

Mine effluents, tailings, and leach pond water can contain many forms of cyanide, each having a different effect on the environment.[419] Measuring the gravity of the environmental loss **(L)** from a cyanide release depends on the precise chemical nature of the cyanide when it escapes. Because different forms of cyanide may be released in a single spill, determining the best way to clean up the release may be difficult. Making matters more complex, the methods of clean up depend on *how* the cyanide was re-

413. *See* DAVID A. DZOMBAK, RAJAT S. GHOSH, & GEORGE M. WONG-CHONG, CYANIDE IN WATER AND SOIL: CHEMISTRY, RISK, AND MANAGEMENT (2006).
414. LABERGE ENVTL. SERVS., CYANIDE – THE FACTS 3 (2001).
415. *Id.*
416. *Id.*
417. NEEDHAM, *supra* note 15, at 40.
418. LABERGE ENVTL. SERVS., *supra* note 414, at 4.
419. *Id.* at 1.

leased; different types of releases call for different clean up techniques.[420] The form of the cyanide is the most critical determinant, however, because it will determine the toxicity of the type of cyanide and its persistence in the environment.[421]

The gravity of a cyanide spill depends on the precise chemical characteristics of the cyanide when it is introduced into the natural environment. Most mine operators are required to monitor only three categories of cyanide:[422]

1. cyanide
2. weak-acid-dissociable (WAD) cyanide
3. total cyanide

Other toxic breakdown products of cyanide, like cyanates, thiocyanates, and cyanogen may also exist and may deleteriously affect water toxicity and thereby potentially harm the environment, but are not typically required by regulators to be monitored.[423]

Free cyanide is the most toxic type of cyanide, and is present in two different forms, HCN (with the hydrogen atom) and CN^- (cyanide ion).[424] Free cyanide has the most potential to cause severe environmental damage if released in substantial amounts.[425] WAD complexes are weak or moderately stable complexes, such as cadmium, copper, and zinc cyanide.[426] These forms of cyanide are fairly soluble in water. While WAD complexes are much less toxic than free cyanide, their dissociation into smaller negatively and positively charged ions, anions and cations, respectively, has the effect of releasing free cyanide, as well as the metal cation that can be extremely toxic. For example, the WAD zinc cyanide, $Zn(CN)_2$, will dissociate readily into the anion $2CN^-$ and the cation Zn^{2+}, which can be toxic.[427]

Other cyanide-related compounds are considered to be toxic to aquatic organisms but generally need to be present in much

420. *Id.* at 3.
421. *Id.* at 1.
422. *See* CYANIDE UNCERTAINTIES, *supra* note 11.
423. *Id.* at 7-10.
424. *See supra* Part III.
425. *Id.*
426. *Id.*
427. *Id.*

higher concentrations than for free cyanide in order to be lethal. Many compounds are volatile or form intermediate toxic compounds and therefore have varying persistence in the environment. Their persistence and toxicity are further influenced by the temperature and pH of the water.[428]

c. The "Location" of the Release

If cyanide is released from a mining operation site, where it is released greatly influences the gravity of harm caused by the spill. Accidental releases on land of either liquid or solid cyanide are easier to clean up and contain than spills or releases into surface or groundwater.[429] Furthermore, the receiving waters possess certain characteristics that react to cyanide spills differently. Based on cyanide's chemical behavior, the water characteristics and qualities that affect the gravity of either a spill or release of cyanide include the size and depth of the water body, exposure to sunlight and air, and the temperature and pH of the water. For example, water bodies with shallow depths and large surface areas increase the degradation of cyanide, making it far less toxic.[430] This degradation is a result of exposure to sunlight and air through oxidation, photodecomposition, and volatilization.[431] These processes work on the cyanide naturally, lowering the concentration of cyanide which in turn decreases the amount of cyanide and time that living organisms are exposed to cyanide. In contrast, cyanide releases into deep lakes could be harmful to aquatic life, especially if these organisms are exposed to high amounts of cyanide over a lengthy period of time.

Cyanide degrades quickly when it is released in a river where the water is flowing and can potentially be diluted by other branch streams. Cyanide degradation in flowing water is accelerated by the presence of fully dissolved oxygen, activities of mi-

428. *Id.* at 4.
429. *See* discussions *supra* pp. 61.
430. *Supra* Part III; *see generally Sodium Cyanide Hazards to Fish*, *supra* note 62; LABERGE ENVTL. SERVS., *supra* note 414.
431. LABERGE ENVTL. SERVS., *supra* note 414, at 2.

crobes and bacteria, and turbulence.[432] The qualities of flowing water permit it to frequently overturn and be exposed to air and sunlight. This natural process dilutes the toxic attributes of cyanide. Deep lakes, on the other hand, see lower rates of cyanide degradation as a result of low levels of ultraviolet radiation from the sun reaching the depths of the water, slower rates of dilution, and little water movement.[433]

Other factors contributing to the harm caused by a cyanide spill include the temperature and pH of the receiving waters. Tests performed in varying water temperatures indicate generally that as temperature increases, the rate of lethal action of the cyanide increases.[434] However, results tend to vary when cyanide levels in the water are very low. The pH of the body of water that the cyanide is released into affects the concentrations of the different forms of free cyanide, and therefore the toxicity of the water.

Two forms of toxic free cyanide include the neutrally charged molecular cyanide, HCN, and the negatively charged cyanide ion, CN^-.[435] As the pH of the receiving water increases, the concentration of HCN decreases and the concentration of CN^- increases. Alternatively, as the pH of the receiving water decreases, in particular below a pH of 9.0 towards neutrality, the concentration of HCN increases rapidly and the concentration of CN^- decreases.[436] Since acute toxicity to fish due to free cyanide has been found to increase with a decrease in pH and higher levels of HCN, it follows that molecular HCN is more toxic than CN.[437] Most toxicity of water polluted mainly with free cyanide would therefore be attributable to the presence of molecular HCN. This is because HCN is a small, uncharged (neutral) molecule that more easily penetrates into the blood and other tissues of organisms than

432. Li Shehong et al., *Natural Cyanide Degradation and Impact on Ili River Drainage Areas from a Goldmine in Xinjiang Autonomous Region, China*, 27 ENVTL. GEOCHEMISTRY & HEALTH 1 (2005).

433. *Id.*

434. PETER DOUDOROFF, TOXICITY TO FISH OF CYANIDES AND RELATED COMPOUNDS: A REVIEW 33 (1976).

435. DEP'T HEALTH & AGING, *supra* note 105.

436. DOUDOROFF, *supra* note 434, at 12-13.

437. *Id.* at 13.

charged molecules.[438] The risk of ecological and aquatic loss **(L)** therefore rises if conditions (e.g., the pH level of receiving waters) are conducive to higher concentrations of HCN.

Environmental damage from a cyanide spill may also be enhanced by the presence of heavy metals. Heavy metals are often found along with cyanide in mine wastes and can increase the negative long-term effects of a cyanide release. Heavy metals are also present in water bodies as a result of industrial, municipal, and urban runoff, as well as natural weathering of soils and rocks. The presence of background heavy metals in water bodies may contribute to the concentration of heavy metals in aquatic resources after a spill of cyanide. Heavy metals containing effluent augment the gravity of harm of the release.

D. Uncertainty Associated with a Risk Assessment (u)

a. Uncertainty About Physical Factors

As with any scientific risk assessment, a risk assessment for the use of cyanide in gold mining must take into account uncertainties that contribute to the calculation of the risk. These uncertainties are often associated with a lack of scientific data and knowledge about the interaction of cyanide and cyanide-containing spills with the environment, in particular with bodies of water, but also with the adverse effects of social amplification of risk.

One of the first sources of uncertainty in a risk assessment involving the use of cyanide in gold mining stems from the lack of adequate local baseline water-quality data.[439] The absence of data makes it difficult to accurately measure the effect of a release by comparing it to pre-existing conditions.[440] The complexity of cyanide-leach gold wastes also means there is some uncertainty in determining the actual chemical components or concentrations

438. *Id.* at 14.
439. ROBERT MORAN, DECODING CYANIDE: AN ASSESSMENT OF GAPS IN CYANIDE REGULATION AT MINES 16 (2002).
440. *Id.*

of such wastes.[441] Many releases contain different forms of cyanide, as well as a variety of breakdown compounds that may be unaccounted for in monitoring, making their quantities and subsequent effects indeterminable.[442] The complex components of releases ensure uncertainty when seeking to ascertain which component or components have caused the toxic responses.[443] In adaddition, some data, like that from the infamous Romanian spill, report only total cyanide and certain selections of other metals from the water samples.[444] But the data does not usually include field measurements of temperature, specific conductance, or pH, which can be some of the most useful data for understanding a spill.[445]

Other uncertainties lie in predicting the long-term effects that the release will have. Techniques commonly used to neutralize spilled cyanide often release unacceptable concentrations of contaminants whose long-term effects on the environment are unknown.[446] Different environmental conditions in areas where a cyanide release occurs also make it problematic to predict how an area will recover after cyanide exposure. Further, many mine-spill investigations are subsidized at least in part with funds from the governments of the country where the operating companies are located.[447] This connection suggests that the reports may be "friendly" to the interests of the operating company, and may not be entirely accurate.[448] Yet another uncertainty results from acid rock drainage problems that can develop many years after a spill. Spent ores or tailings that contain significant sulfide compounds are the cause of acid rock drainage problems and can present much more costly contamination than cyanide and its related

441. ROBERT MORAN, MORE CYANIDE UNCERTAINTIES: LESSONS FROM THE BAIA MARE, ROMANIA, SPILL – WATER QUALITY AND POLITICS 6-7 (2001) [hereinafter MORE CYANIDE UNCERTAINTIES].

442. *Id.*

443. *Id.* at 8.

444. *Id.* at 7.

445. *Id.* at 7.

446. LABERGE ENVTL. SERVS., *supra* note 414, at 3.

447. MORE CYANIDE UNCERTAINTIES, *supra* note 441, at 11.

448. *Id.*

products although its effects can take up to decades to become visible.[449]

b. Uncertainty Involving Risk Amplification

The level of risk in a risk assessment depends also on the degree of risk amplification, and this uncertainty must be considered when determining risk acceptance. The presence of scientific uncertainty alone should not serve as a justification for a particular policymaking action.[450] Relevant risk managers, especially mining operators, must consider SARF and the social amplification of risks, that are not correlated to the true risks, but which may lead to insurmountable political or regulatory obstacles.[451] Governmental agencies face similar uncertainty resulting from risk amplification when they seek to implement zoning, permitting, infrastructure development, and long-term community planning based on mining projects. Socially amplified perception of risk can devastate these government plans, if the risk amplification creates overwhelming opposition to an otherwise permitted mine project. If either mining operators or governments favoring mines wish to avoid negative consequences of social activism grounded in SARF, they should first realize the power of sentiment based on SARF, and then proactively mitigate uncertainty associated with the perceived risk of using cyanide in a mining operation.

E. Mitigation (m)

One important factor that lowers the risk of cyanide use is the ability of mine operations and government supporters of mines to mitigate (1) the possibility that the risk will be amplified because the mine will use a stigmatized chemical—cyanide, and (2) both the likelihood that a toxic cyanide release will occur, and the environmental effects should a release occur.

449. *Id.*
450. *See* Greater Yellowstone Coalition, Inc. v. Servheen, 665 F.3d 1015 (9th Cir. 2011).
451. *See generally* Sunstein, *supra* note 17; Slovic, *Perception of Risk*, *supra* note 350, at 285.

a. Mitigate the Perception of Risk

Successful mine operators understand that in addition to mitigating potential negative environmental effects of cyanide, they must also address the perception of the high risk of cyanide related events. This perception of risk is held by neighbors of the mine, environmental organizations, and the general public. Those who use cyanide to extract essential compounds from ore are at the mercy of the likely Social Amplification of Risk that follows from the use of a substance that has so many negative emotional associations.[452] Those interested in developing mines that use cyanide can mitigate risk amplification by considering the "affect heuristic" which scholars studying risk amplification have observed.[453] Pursuant to this affect heuristic, if a group's feelings (not their thinking) toward an activity are favorable, they judge the risks as low and the benefits as a high; if their feelings are unfavorable, they tend to judge the opposite.[454] This process suggests that if feelings, not cognitive judgments, guide perceptions of risk and benefit, then providing information about the activity's benefit should change perception of risk.[455] For example, information stating that the benefits of mining operations with cyanide are high (e.g., high employment, low environmental risk) would lead to a more positive outlook about the operation that would decrease the perception of risk.

b. Mitigating the Environmental Consequences of Cyanide

Mining operations that use cyanide have numerous options available to them for mitigating the toxic effects of cyanide to the environment, while still being able to utilize the cyanide effective-

452. *See* Scott Slovic & Paul Slovic, *Numbers and Nerves, Toward An Affective Apprehension of Environmental Risk* 79-80, *in* THE FEELING RISK, NEW PERSPECTIVES ON RISK PERCEPTION (2010).

453. PAUL SLOVIC ET AL., RISK AS ANALYSIS AND RISK AS FEELINGS: SOME THOUGHTS ABOUT AFFECT, REASON, RISK, AND RATIONALITY 21-27 (2003), *available at* http://dccps.nci.nih.gov/brp/presentations/slovic.pdf; Sunstein, *supra* note 17, at 2262.

454. *Id.*

455. *Id.* at 26.

ly for recovering valuable metals, mainly gold.[456] Mitigation efforts have to reflect the high variability of cyanide compounds from site to site, so feasibility must also be factored into the effectiveness of a given technology. But for every mine that uses cyanide, some mitigation is possible that reduces the risk of environmental harm. Mitigation includes pre-mine assessment of site conditions, mine design, cyanide treatment, and spillage containment.

1. Pre-Mine Site Assessment

Before a mine is operational, experts usually perform environmental studies to give the mine operators, regulatory bodies, and public an understanding of what the pre-mine conditions are like in the area, usually as part of a regulatory requirement. The mitigation design of a mining operation will depend greatly on the conclusions of the engineering and environmental studies conducted during this planning stage of development.

Water quality after a cyanide spill is the predominant concern for those opposed to mining operations that use cyanide in their gold-recovery process, and miners conduct much of their design and baseline studies in order to address this issue. During the planning process, hydrologic modeling is conducted for both groundwater and surface water systems. This up-front investigation ensures proper design of various water containing features, water disposal options, precipitation thresholds, and long-term water resource impacts for water management purposes. Planners use other modeling procedures to aid mining operations in design considerations, especially with respect to water quality.[457]

When considering mitigation design at a mining operation, it is first necessary to understand the hydrologic environment. The hydrologic context is critical because water is usually the culprit when a breach of cyanide occurs. The hydrologic studies and

456. *See* EPA, ENGINEERING ISSUE: MANAGEMENT AND TREATMENT OF WATER FROM HARD ROCK MINES (2006), *available at* http://nepis.epa.gov.

457. *See* NEVADA BUREAU OF LAND MANAGEMENT WATER RESOURCE DATA AND ANALYSIS POLICY FOR MINING ACTIVITIES, http://www.blm.gov/pgdata/etc/medialib/blm/nv/minerals/mining.Par.42873.File.dat/WaterResDataPolicyForMining.pdf (last visited Apr. 8, 2013).

modeling conducted prior to operation of the mine aid in the overall design of the mine. Such studies assess water quality for both groundwater and nearby surface waters, which can then be used to model a catastrophic precipitation event. The results of these models may then be factored into the design of tailings impoundments and secondary containments, and can help determine placement of permanent monitoring wells.[458] On-going, frequently scheduled groundwater and surface water sampling conconducted as part of a responsible water management plan at a mine ensures that a cyanide spill has not occurred. Conversely, such samplings may also inform a mining operation that a breach has occurred so that efforts can be made to stop further contamination and remediate the spill.[459]

Because cyanide readily forms compounds with many constituents found in the soil and ore at a site, such as iron, characterizing the geology of a mine site is also important. Geologic knowledge is beneficial for leaching purposes, because it helps to determine the amount of cyanide that is necessary to leach the gold; it also reveals to the mine operators what species of cyanide might exist in tailing slurries and impoundments.[460] Understanding what type of cyanide is present permits operators to plan for the most effective treatment methods, because in some cases the treatment of contaminated water or slurries might in itself be toxic to living organisms.[461] Also, using the least amount of cyanide possible is one way to reduce the likelihood of a catastrophic spill by limiting the amount of cyanide that might escape from a mine.[462]

Other preliminary considerations that are important to the overall cyanide mitigation design are environmental studies, including biological and geotechnical studies. For instance, if the mine location is in an area where there are large populations of wading birds, it would be advisable to limit the surface area of a tailings pond and install netting or floating balls to deter the

458. *See id.* (discussing pre-planning procedures to be conducted by the mine operator and government).

459. *See* LOGSDON ET AL., *supra* note 19, at 3-5.

460. NEVADA BUREAU OF LAND MANAGEMENT, *supra* note 457, at 10.

461. LABERGE ENVTL. SERVS., *supra* note 414, at 3.

462. *See* LOGSDON ET AL., *supra* note 19, at 33.

birds from landing on the pond. Geotechnical studies consider hazards such as the potential for earthquakes and subsidence, which might occur, compromising the integrity of mine facilities. If improperly designed, heap leach pads and tailings impoundments could release cyanide into nearby streams. Thorough geotechnical studies ensure proper structural design of the mine features, which in turn become part of an effective pre-mine cyanide mitigation plan.

2. Mine Design

Some mine-design mitigation measures are universal, such as using lined heap leach pads; however, the type of liner and the number of impermeable liners used can vary from site to site.[463] Other mitigation and regulatory measures used to further water quality and protect wildlife include water storage and stormwater management plans under the Clean Water Act[464] and tailings characterizations subject to the Resource Conservation Recovery Act.[465]

Physical barriers, such as fencing and netting over and around heap leach pads and tailings ponds, may be installed to prevent wildlife from becoming exposed to cyanide. Some of these measures are subject to regulation under the Migratory Bird Treaty Act,[466] and various State wildlife laws or operational permit conditions.

3. Treatment of Cyanide

Mining operations may seek to prevent a cyanide spill by recycling or treating the cyanide solutions, and by adding special substances to the tailing slurries.[467] Mining operations often recycle or re-use the cyanide solutions many times for economic purposes.[468] Treating the solution reduces the levels of free cyanide, and reducing the total amount of cyanide present at a min-

463. EPA, *supra* note 133, at 19.
464. 33 U.S.C §§ 1251, 1252a, 1291 (2006).
465. 42 U.S.C. § 6901 (2006).
466. 16 U.S.C. § 703 (2006).
467. *See* LOGSDON ET AL., *supra* note 19, at 33.
468. *Id.* at 33.

ing operation in turn reduces the risk of a spill.[469] Water treatment for process solutions and tailing slurries can also be effective in preventing a catastrophic cyanide spill from doing environmental damage by lowering the cyanide content.[470]

4. Remediation After a Spill

Mining operations might respond to spills containing cyanide by imposing physical containment on site in order to divert the spill away from sensitive areas.[471] Notifying down-stream surface or groundwater users is also wise.[472] The first line of defense in the event of a spill is containment and treatment at the source. If, however, a cyanide spill reaches a stream, there is little that can be done to treat the stream.[473] Post-spill river treatment is futile because many treatment methods might lead to chemical and physical reactions that can be fatal to aquatic life.[474] It is far more common to allow for natural attenuation of the cyanide through volatilization, biodegradation by microbes, and complexation with constituents in the streambed.[475] Depending on the extent of the spill, the time it takes to flush the cyanide from the water system varies; the important fact is that cyanide does not persist in the environment for long periods of time and does not bioaccumulate.[476]

The use of cyanide by the mining industry is not unique. Approximately 1.4 million tons of cyanide is manufactured annually for use in electroplating, case-hardening of metals, base metal flotation, coal gasification, fumigation/pest control, organic synthesis (nylon and acrylics), and mining industries.[477] Major cyanide releases or spills are mostly attributable to the metal-finishing

469. *See id.*; NEEDHAM, *supra* note 15.
470. LOGSDON ET AL., *supra* note 19.
471. *Id.* at 4.
472. *Id.*
473. *Id.*
474. *Id.*
475. LABERGE ENVTL. SERVS., *supra* note 414.
476. CYANIDE HAZARDS TO FISH, WILDLIFE, AND INVERTEBRATES, *supra* note 157.
477. LOGSDON ET AL., *supra* note 19, at 5; WORLD HEALTH ORG., CYANIDE IN DRINKING WATER: A BACKGROUND DOCUMENT FOR THE DEVELOPMENT OF WHO GUIDELINES FOR DRINKING WATER QUALITY (2007).

industry, iron and steel mills, and the organic synthesis industry,[478] *not mining.*[479]

478. U.S. DEP'T OF HEALTH & HUMAN SERVS., TOXICOLOGICAL PROFILE FOR CYANIDE (2006), *available at* http://www.atsdr.cdc.gov/ToxProfiles/tp8.pdf.

479. EPA, AN EXPOSURE AND RISK ASSESSMENT FOR CYANIDE (1981), *available at* http://nepis.epa.gov.