IF WE ONLY HAD A BRAIN: Toothless Aquatic Code Allows Deadly, Brain-Eating Zombie Amoeba To Flourish in Arizona Splash Pads and Water Playgrounds

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I. INTRODUCTION

It starts with a fever. A splitting headache. Vomiting, fatigue, an earache—then the secondary symptoms begin. Vision loss. Stiff neck. Lethargy, confusion, inability to walk, an aversion to light. Hallucinations. Doctors scramble to make a diagnosis, attempting treatment for bacterial meningitis, viral encephalitis, herpes, or other rare diseases, but nothing works.[1] Finally, a coma. Death follows within three days.[2]

Diagnosis is usually done post-mortem: the culprit is primary amebic meningoencephalitis, or PAM.[3] The disease is identified via a cerebrospinal fluid tap under a microscope. Peering in, you can see free living amoeba swimming around in the spinal fluid.[4]

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1. *See* Rikesh Baral & Binit Vaidya, *Fatal Case of Amoebic Encephalitis Masquerading as Herpes*, 5 OXFORD MED. CASE REPORTS. 146, 148 (2018), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5934662/pdf/omy010.pdf [https://perma.cc/HSM6-WZZV].

2. Linda G. Capewell et al., *Diagnosis, Clinical Course, and Treatment of Primary Amoebic Meningoencephalitis in the United States, 1937–2013*, 4 J. PEDIATRIC INFECTIOUS DISEASES SOC'Y e68, e68–e75 (2015).

3. *Primary Amebic Meningoencephalitis*, STEDMAN'S MEDICAL DICTIONARY (28th ed. 2006).

4. *Parasites*—Naegleria fowleri—*Primary Amebic Meningoencephalitis (PAM)—Amebic Encephalitis*: *Diagnosis & Detection*, CTR. FOR DISEASE CONTROL & PREVENTION (last reviewed Feb. 28, 2017), https://www.cdc.gov/parasites/naegleria/diagnosis.html [https://perma.cc/L55Z-PSWV].

The name of the amoeba that causes this invasive and rapidly fatal disease is *Naegleria fowleri* ("*N. fowleri*").[5] Under the microscope, it looks innocuous, but in reality, it's a cold-blooded killer out for your brains. Deemed the "zombie amoeba,"[6] *N. fowleri* goes up the nose, burrows in the brain, and begins eating brain tissue, while causing a host of unpleasant symptoms.[7]

There is no characteristic clinical presentation of the PAM infection.[8] Because these symptoms are so general, clinical presentation with PAM is frequently mistaken for other infections, like bacterial meningitis and viral encephalitis, or even herpes.[9] As a result, PAM carries a 97% mortality rate—and that figure only includes the cases that were diagnosed.[10] In the United States, more than 145 cases of PAM have been reported.[11] Eight of these cases were from Arizona.[12]

Arizona is the perfect breeding ground for these deadly brain-eating amoebae, yet its codes, regulations, and laws are insufficient. Arizona's current laws fail in three ways: 1) splash pad construction standards not only fail to create guidelines for building safe splash pads, *they simply don't exist*; 2) chlorination guidelines are unclear and allow amoeba to flourish in areas that appeal to the most vulnerable population; and 3) inspections are infrequent, or in many cases, non-existent, making compliance essentially discretionary.

This Comment argues that instances of PAM can be eradicated by adopting and maintaining basic water quality standards for all splash pads in Arizona. Part I provides an overview of the amoeba in the United States. Part II discusses the current Arizona regulations and their effectiveness at preventing amoebic infection. Part III examines how other jurisdictions

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5 *Primary Amebic Meningoencephalitis*, STEDMAN'S MEDICAL DICTIONARY (28th ed. 2006).

6. Maya Liepert, *Zombie Amoebas: Your Brain Is at Risk*, COMMUNICATING SCI. (Oct. 1, 2018), https://blogs.ubc.ca/communicatingscience2018w109/2018/10/01/zombie-amoebas/ [https://perma.cc/UFS6-GYQQ].

7. *Brain-Eating Amoeba*, WEBMD, https://www.webmd.com/brain/brain-eating-amoeba [https://perma.cc/R8LZ-EZB5].

8. Baral & Vaidya, *supra* note 1, at 148.

9. *Id.*; *see also* Almea Matanock et al., *Estimation of Undiagnosed* Naegleria fowleri *Primary Amebic Meningoencephalitis, United States*, 24 EMERGING INFECTIOUS DISEASES 162, 163–64 (2018).

10. Baral & Vaidya, *supra* note 1, at 148.

11. *Parasites*—Naegleria fowleri—*Primary Amebic Meningoencephalitis (PAM) — Amebic Encephalitis: Number of Case–Reports of Primary Amebic Meningoencephalitis by State of Exposure*, CTR. FOR DISEASE CONTROL & PREVENTION (Apr. 30, 2019), https://www.cdc.gov/parasites/naegleria/state-map.html [https://perma.cc/4QWM-DT56].

12. *Id.*

handle the amoeba problem, either through premises liability or adoption of the Model Aquatic Code. Finally, Part IV offers statutory and regulatory fixes for Arizona to consider when the aquatic code comes up for editing in the legislature.

A. The N. Fowleri Infection.

N. fowleri is a free-living amoeba that flourishes in freshwater.[13] For many years, *N. fowleri* was thought to be localized in southern states with high temperatures, but recent infections from *N. fowleri* exposure in northern states show the ubiquitous nature of the amoeba.[14] *N. fowleri* can exist in three forms, depending on environmental conditions.[15] In favorable environmental conditions (high levels of nutrients and water), the amoeba takes a trophozoite form, where the amoeba can metabolize, reproduce, and infect humans.[16] In a famine environment, but still in water, the amoeba takes a flagellate stage, enabling long distance movement to pursue nutrients.[17] Finally, in a famine, no-water environment, the amoeba can transform into an encysted dormant phase.[18] Though the encysted form is not infective, upon rehydration, the cyst can return to the virulent trophozoite stage.[19]

Infection occurs when the amoeba is aspirated into the nose and attaches to the mucosal membrane.[20] The amoeba crosses the cribriform plate into the central nervous system and burrows in the frontal lobe.[21] Once it burrows in the brain matter, symptoms onset suddenly.[22] Patients experience a headache, high fever, stiff neck, nausea, vomiting, irritability, and restlessness.[23] Later symptoms of PAM infection are bizarre: photophobia (aversion to light), diplopia (double vision), confusion, hallucinations, and other inexplicable

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13. Capewell et al., *supra* note 2, at e68.
14. *Id.*
15. Ruqaiyyah Siddiqui et al., *Biology and Pathogenesis of* Naegleria Fowleri, 164 ACTA TROPICA 375, 376 (2016).
16. *Id.*
17. *Id.*
18. *Id.* Encysted free living amoeba are spherical and have hard coats made of proteins and cellulose. *See* Emilie Fouque et al., *Cellular, Biochemical, and Molecular Changes During Encystment of Free-Living Amoebae*, 11 EUKARYOTIC CELL 382, 382 (2012).
19. Bibiana Chávez-Munguía et al., *Ultrastructural Study of the Encystation and Excystation Processes in* Naegleria *Sp.*, 56 J. EUKARYOTIC MICROBIOLOGY 66, 66 (2009).
20. Govinda S. Visvesvara, *Free-Living Amebae as Opportunistic Agents of Human Disease*, 1 J. NEUROPARASITOLOGY 1, 6 (2010).
21. *Id.*
22. *Id.* at 7.
23. *Id.*

behavior.[24] Popular culture has deemed *N. fowleri* the "zombie amoeba" or the "brain-eating amoeba" due to its unique mechanism of infection.[25]

PAM infection only results when the victim inhales water containing the amoeba into the nasal cavity—stomach acid neutralizes the amoeba if it is swallowed.[26] This nasal inhalation requirement leaves certain populations particularly vulnerable to infection. PAM disproportionately affects healthy young boys who are exposed to warm water during recreational activities.[27] PAM infection can come from freshwater lakes, rivers, spas, untreated tap water, and swimming pools.[28] Because the amoeba must enter through the nose, risk factors for PAM infection include any activity where water is splashed or forced through the nasal passages, such as diving without a nose plug or using a Neti pot.[29]

Another activity that presents a huge infection risk comes in the form of splash pads and water playgrounds.[30] The shooting jets and spraying fountains rapidly aerosolize the amoeba.[31] Children playing in the fountain inhale the amoeba through their nasal passages, providing a port of entry to the brain.[32] Adding to the danger, most splash pads circulate non-chlorinated

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24. *Id.*

25. Liepert, *supra* note 6.

26. Abe Aboraya & Michael Tomsic, *A Young Woman Dies, a Teen Is Saved After Amoebas Infect the Brain*, HAVASU NEWS (Sept. 5, 2016), https://www.havasunews.com/a-young-woman-dies-a-teen-is-saved-after-amoebas/article_91c52cdc-73f8-11e6-94e9-93dd913ed614.html [https://perma.cc/L28D-JMAU]; *see also* JENNIFER R. COPE & IBNE K. ALI, PRIMARY AMEBIC MENINGOENCEPHALITIS: WHAT HAVE WE LEARNED IN THE LAST FIVE YEARS? (2016), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5100007/ [https://perma.cc/72VS-29C3].

27. Cope & Ali, *supra* note 26, at 2. Researchers hypothesize that boys are disproportionately infected because they are more likely to jump, slide and play in amoeba-ridden mud than girls. *See* J.S. Yoder et al., *The Epidemiology of Primary Amoebia Meningoencephalitis in the USA, 1962–2008*, 138 EPIDEMIOLOGY & INFECTION 968, 972 (2009).

28. Ruqaiyyah Siddiqui & Naveed Ahmed Khan, *Primary Amoebic Meningoencephalitis Caused by* Naegleria Fowleri*: An Old Enemy Presenting New Challenges*, PLOS: NEGLECTED TROPICAL DISEASES (Aug. 14, 2014), https://journals.plos.org/plosntds/article?id=10.1371/journal.pntd.0003017 [https://perma.cc/2FE5-T4U4].

29. *Id.*

30. *See* P.J. Lassek, *Splash Pad: Illnesses: City Pays Settlement for Deaths*, TULSA WORLD (Feb. 14, 2007), https://www.tulsaworld.com/archives/splash-pad-illnesses-city-pays-settlement-for-deaths/article_326fefed-e9c6-5776-8531-2c21835ae618.html [https://perma.cc/AJ4A-UQQA].

31. For a description of fountains, nozzles, and jets, see *Splash Pad Water Play Features*, MY SPLASH PAD, https://mysplashpad.net/water-play-features/ [https://perma.cc/VTL6-YXYE].

32. COPE & ALI, *supra* note 26.

water, straight from the municipal city water supply.[33] *N. fowleri* flourishes in this water supply; on average, there are 30 amoeba per liter of water in a drinking water storage tower in the summer.[34]

The first case of PAM was described in the United States in 1966.[35] One hundred and forty-five PAM infections have been diagnosed in the United States through 2018.[36] About 75% of the PAM infections in the United States were contracted from a warm freshwater lake or river.[37] The remaining 25% of cases were contracted from municipal water sources that are generally viewed as safe.[38]

On July 27, 2013, a healthy four-year-old-boy began exhibiting the symptoms of PAM: diarrhea, severe headache, high fever, and "staring spells" where he was "unresponsive with his eyes fixed and opened."[39] His condition continually worsened until he was declared brain dead.[40] His family decided to withdraw life support on August 1, 2013, only five days after his initial presentation to the emergency department.[41] Brain specimens collected from his autopsy were sent to the Center for Disease Control and Prevention, and the CDC determined that he had suffered from PAM due to *N. fowleri*.[42] This post-mortem diagnosis launched a large epidemiologic investigation, and researchers determined the source of the amoeba was tap water.[43]

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33. *See* Paul Steinbach, *Key Considerations When Building a Splash Pad*, ATHLETIC BUSINESS (Aug. 2014), https://www.athleticbusiness.com/aquatic/key-considerations-when-building-a-splash-pad.html [https://perma.cc/9PN7-PU3J] ("In a flow-through system, water from a potable source is pumped onto the pad and allowed to drain into a municipality's storm system or, quite often, to be repurposed as irrigation. This method requires no water treatment and testing (nor the corresponding expense and staffing expertise) . . . .").

34. Alexandre Taravaud et al., *Enrichment of Free-Living Amoebae in Biofilms Developed at Upper Water Levels in Drinking Water Storage Towers: An Inter- and Intra-Seasonal Study*, 633 SCI. TOTAL ENV'T 157, 157 (2018) (testing three storage water towers in metropolitan Paris).

35. COPE & ALI, *supra* note 26, at 2.

36. *Parasites*—Naegleria fowleri—*Primary Amebic Meningoencephalitis (PAM) — Amebic Encephalitis*: *Sources of Infection and Risk Factors,* CTR. FOR DISEASE CONTROL AND PREVENTION (Apr. 4, 2019), https://www.cdc.gov/parasites/naegleria/infection-sources.html [https://perma.cc/S6PD-CYDZ].

37. *Id.* ("In the United States and the rest of the world, PAM is primarily spread via swimming in warm freshwater lakes and rivers (about 3 out of 4 U.S. infections from 1962-2018).").

38. *See generally* Safe Drinking Water Act, Pub. L. No. 104–182, 110 Stat. 1613 (1996).

39. Jennifer R. Cope et al., *The First Association of a Primary Amebic Meningoencephalitis Death with Culturable* Naegleria fowleri *in Tap Water from a US Treated Public Drinking Water System*, 60 CLINICAL INFECTIOUS DISEASES e36, e37 (2015).

40. *Id.*

41. *Id.*

42. *Id.*

43. *Id.* at e37–e39.

Right before his death, the boy played in his yard on a slip 'n slide, which was connected to two garden hoses that drew tap water from the outdoor faucets.[44] As he slid both head and feet first, he splashed into a pool of muddy water that collected at the end of the slide.[45] This splashing allowed the tap-water-based amoeba to aerosolize and enter his nasal passage.[46] 25% of water samples taken from the house tested positive for *N. fowleri*.[47] The water contained no detectable chlorine residual and the water temperature was relatively high ("greater than 30°C at 3 of the 4 sampling locations") where the deadly amoeba was found.[48]

Other cases of PAM have been contracted from using contaminated tap water for nasal irrigation in a Neti pot.[49] In June of 2011, a twenty-eight-year-old Louisiana man contracted PAM from tap water he was using to fill his Neti pot.[50] A couple months later, in September of 2011, another Louisiana Neti pot user contracted PAM from tap water.[51]

Two Arizona infections occurred from the same municipal tap water source in 2002.[52] Two five-year-old boys, Davy Luna of Glendale and Zach Stalls of Peoria, both became sick in October of 2002 and were hospitalized with what was later determined to be *N. fowleri* infection.[53] Both boys most likely got the infection from bathing in contaminated water.[54] After the investigation, epidemiologists collected nineteen samples from the homes of the two children.[55] The nineteen samples were collected from the bathrooms

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44. *Id.*
45. *Id.*
46. *See id.* at e37–e41.
47. *Id.* at e39.
48. *Id.* Thirty degrees Celsius is equal to eighty-six degrees Fahrenheit.
49. Jonathan S. Yoder et al., *Primary Amebic Meningoencephalitis Deaths Associated with Sinus Irrigation Using Contaminated Tap Water*, 55 CLINICAL INFECTIOUS DISEASES e79, e82 (2012).
50. *Id.* at e80.
51. *Id.* at e82.
52. Francine Marciano-Cabral et al., *Identification of* Naegleria fowleri *in Domestic Water Sources by Nested PCR*, APPLIED & ENVTL. MICROBIOLOGY (2003), https://aem.asm.org/content/69/10/5864 [https://perma.cc/4BET-HRBN].
53. *Parasite Found in Valley Company's Water System*, ARIZ. DAILY SUN (Nov. 2, 2002), https://azdailysun.com/parasite-found-in-valley-company-s-water-system/article_b2a5a5fa-b122-57b2-8c06-3d2f39f7547d.html [https://perma.cc/PJ86-3GQ7].
54. Fourth Amended Complaint, Wrongful Death, Negligence, Products Liability, Strict Liability, Punitive Damages at 4–5, Luna v. Rose Valley Water Co., No. CV2002-070537 (Maricopa County Super. Ct. Jan. 9, 2004).
55. Marciano-Cabral et al., *supra* note 52.

and kitchen.[56] Seventeen of these samples tested positive for the presence of the brain-eating amoeba.[57]

PAM infections have also occurred recently. In July 2019, fifty-nine year old Eddie Gray died after swimming in a man-made lake.[58] Ten-year-old Lily Avant passed away a week after swimming near her home over Labor Day weekend in 2019.[59] In late September 2018, a twenty-nine-year-old surfer visited a wave pool in Waco, Texas, and was dead by the end of the week.[60] In 2015, an Oklahoman died after swimming in Lake Murray.[61] In 2014, a nine-year-old swimmer died after swimming in several local lakes.[62] Twelve-year-old Zachary Reyna of Florida became infected after knee-boarding in fresh water in 2013.[63] As the death toll continues to rise, the gap between protective measures and the risk is becoming painfully clear.

Though this problem is global,[64] Arizona is uniquely poised to change its trajectory of public protection against *N. fowleri*. In the summer of 2017, the Arizona Department of Environmental Quality submitted a Notice of Proposed Rulemaking to the Secretary of State to reassess and revamp its water quality governance.[65] Arizona is currently a battleground state between two visions of how swimming pools and splash pads should be governed.[66]

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56. *Id.*

57. *Id.*

58. Haley Weiss, *The Brain-Eating Amoeba Is a Near Perfect Killer*, ATLANTIC (July 29, 2019), https://www.theatlantic.com/science/archive/2019/07/how-brain-eating-amoeba-kills/594964/ [https://perma.cc/K3JG-D6KM].

59. Amir Vera, *The 10-Year-Old Girl Who Contracted a Brain-Eating Amoeba While Swimming Has Died*, CNN (Sept. 16, 2019, 5:27 PM), https://www.cnn.com/2019/09/16/us/texas-brain-eating-amoeba-girl-dies-trnd/index.html [https://perma.cc/4AJN-NR8Z].

60. *Texas Surf Resort Closed for Testing After NJ Man Dies from 'Brain-Eating Amoeba*,*'* N.Y. NBC (Oct. 1, 2018, 7:43 AM), https://www.nbcnewyork.com/news/local/Texas-Surf-Resort-Closed-for-Testing-After-NJ-Man-Dies-From-Brain-Eating-Amoeba-494737451.html [https://perma.cc/UR4Y-M4WF].

61. Holly Yan, *Brain-Eating Amoeba Kills 14-Year-Old Star Athlete*, CNN (Aug. 31, 2015, 5:32 PM), https://www.cnn.com/2015/08/31/health/brain-eating-amoeba-deaths/index.html [https://perma.cc/MH3T-4BJM].

62. *Id.*

63. *Id.*

64. *Naegleriasis Global Impact*, CDIPD, http://www.cdipd.org/index.php/naegleriasis-global-impact [https://perma.cc/JC6V-8AE9] ("*Naegleria fowleri* has been detected on all continents except Antarctica.").

65. Department of Environmental Quality – Environmental Reviews and Certification, Notice of Proposed Rulemaking, Ariz. Admin. Code R18-5-201 to -250 (June 21, 2017), http://static.azdeq.gov/legal/proposed_model_aquatic.pdf [https://perma.cc/6UYS-PAN6].

66. Rebecca Robledo, *Arizona Is a Battleground State for International Swimming Pool and Spa Code and the Model Aquatic Health Code*, AQUATICS INT'L (Oct. 4, 2017),

Yet, progress has stagnated, with no revisions to the laws; the current administrative code remains in place.[67]

B. Arizona Public Pool Water Quality Governance.

Arizona governs public and semipublic pool and spa water quality. This area of administrative law falls under the purview of both the Department of Health Services (DHS) and the Department of Environmental Quality. DHS's stated mission is to ensure the health of Arizona children and adults through care, policy, and science.[68] DHS has two potential sources of authority to regulate and prevent amoebic infection: the disease prevention and control program, and the environmental health program.[69] These stated programs overlap with the Arizona Department of Environmental Quality, whose mission is to "protect and enhance public health and the environment in Arizona."[70] As such, both departments promulgate regulations that impact the operation of pools and splash pads in Arizona.

1. Department of Health Services Regulations

Title 9, Chapter 8 of the Arizona Administrative Code falls under the purview of the Department of Health Services Food, Recreational, and Institutional Sanitation.[71] Titled "Public and Semipublic Swimming Pool and Spa Water Quality and Disinfection Standards," the regulations dictate what an owner of a public or semipublic swimming pool must do.[72] The Department of Health Services regulations under Title 9 cross-define "public swimming pool" and "semipublic swimming pool" to reference the Title 18 definitions under the Department of Environmental Quality.[73]

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https://www.aquaticsintl.com/facilities/arizona-is-a-battleground-state-for-international-swimming-pool-and-spa-code-and-the-model-aquatic-health-code_s [https://perma.cc/Y25Q-Z262]. This Comment discusses the two competing codes in Part D, *infra*.

67. ARIZ. REV. STAT. § 41-1021(A)(4) (2020) (a rulemaking proceeding expires one year after the notice is published in the register if the agency has not submitted the rule to the council for review and approval); *see* e-mail from Heidi M. Haggerty Welborn, Legal Specialist, Water Quality Division, Ariz. Dep't of Envtl. Quality to author (Oct. 11, 2018) (on file with author).

68. *About Us*, ARIZ. DEP'T HEALTH SERVS., https://www.azdhs.gov/about.php [https://perma.cc/A3BR-VGET].

69. *Id.*

70. *About Us*, ARIZ. DEP'T ENVTL. QUALITY (Oct. 3, 2019, 6:45 PM), https://azdeq.gov/AboutUs [https://perma.cc/8UFR-2M7G].

71. ARIZ. ADMIN. CODE §§ R9-8-101 to -1649 (2020).

72. *Id.* § R9-8-803(A).

73. *Id.* § R9-8-801.

The Code's first requirement is that the "swimming pool or spa" be "filled only with potable water."[74] Second, the water must maintain the minimum water quality standards during the hours and seasons where the pool is open for water contact recreation.[75]

Next, the Code dives into the actual water quality standards. Operators of a public or semipublic swimming pool are given three chemical disinfection standards to choose from:

> An operator of a public or semipublic swimming pool shall ensure that the water in the swimming pool meets one of the following chemical disinfection standards:
>
> 1. A free chlorine residual between 1.0 and 3.0 ppm as measured by the N, N-Diethyl-p-phenylenediamine test,
>
> 2. A free bromine residual between 2.0 and 4.0 ppm as measured by the N, N-Diethyl-p-phenylenediamine test, or
>
> 3. An oxidation-reduction potential equal to or greater than 650 millivolts.[76]

Spas, in contrast, have slightly stricter chemical disinfection standards:

> The water in the spa meets one of the following chemical disinfection standards:
>
> a. A free chlorine residual between 3.0 and 5.0 ppm as measured by the N, N-Diethyl-p-phenylenediamine test,
>
> b. A free bromine residual between 3.0 and 5.0 ppm as measured by the N, N-Diethyl-p-phenylenediamine test, or
>
> c. An oxidation-reduction potential equal to or greater than 650 millivolts.[77]

Additionally, the Code sets out some visual standards for pool and spa cleanliness. For example, the "surface of the water . . . [must be] free from scum and floating debris,"[78] and "[t]he bottom and sides of the swimming pool . . . [must be] free from sediment, dirt, slime, and algae."[79] Ultimately,

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74. *Id.* § R9-8-803(A)(1).

75. *Id.* § R9-8-803(A)(2)(a).

76. *Id.* § R9-8-803(D). Free chlorine is the chemically active chlorine that is available to bind with amines to disinfect a pool. *See* Matt Giovanisci, *How To Use Pool Shock*, SWIM U. (July 3, 2019), https://www.swimuniversity.com/pool-shock/ [https://perma.cc/8TLA-9WXL]. In contrast, combined chlorine is the term used to describe free chlorine once it reacts. *Id.*

77 ARIZ. ADMIN. CODE § R9-8-803(E)(3).

78. *Id.* § R9-8-803(A)(3).

79. *Id.* § R9-8-803(A)(4).

the water must be "sufficiently clear so that the main drain in the swimming pool or spa is visible from the deck of the swimming pool or spa."[80]

Pool or spa operators have a relatively large degree of freedom in reaching these disinfection standards. The Code sets out only a few guidelines for chemical safety: the operator is prohibited from using chloramine as a primary disinfectant or dumping a gaseous disinfectant directly into the pool.[81] The Code liberally allows the application of dry or liquid disinfectant directly into the pool, but limits this application to shock treatment only, not for routine disinfection.[82]

In terms of record keeping, the Code mandates that the operator maintain a daily operating log, dating back twelve months to demonstrate "the chemical disinfection level, pH, total alkalinity, and temperature of the water."[83] This log must be made "available to a regulatory authority or a member of the public upon request."[84]

2. Department of Environmental Quality Regulations

The Department of Environmental Quality also promulgates regulations about swimming pool and spa water quality in Title 18, Chapter 5.[85] In the section titled "Disinfection," the regulations allow disinfection to be "accomplished by chlorination or by another method that is approved by the Department" as long as the method "effectively maintain[s] an adequate disinfectant residual in the water."[86] This adequate disinfectant level is the same as options one and two given to operators of public or semipublic pools and spas in Title 9, Chapter 8: both require "a free chlorine residual of 1.0 to 3.0 ppm" for pools and "a free chlorine residual of 3.0 to 5.0 ppm" for spas; or, in the alternative, "a bromine residual of 2.0 to 4.0 ppm" for pools and "a bromine residual of 3.0 to 5.0 ppm" for spas.[87] Title 18 does *not* authorize the third method of disinfectant—the oxidation-reduction potential of 650 millivolts.[88] The rest of the Chapter covers gaseous chlorine cylinder safety,[89]

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80. *Id.* § R9-8-803(A)(2)(d).
81. *Id.* § R9-8-803(B)(1)–(2).
82. *Id.* § R9-8-803(B)(3)–(4). "Shocking" a pool means adding a large amount of free chlorine to negate the buildup of chloramines. Giovanisci, *supra* note 76.
83. ARIZ. ADMIN. CODE § R9-8-803(A)(5)–(6).
84. *Id.* § R9-8-803(A)(6).
85. *Id.* § R18-5-101 to -509 (2020).
86. *Id.* § R18-5-234(A).
87. *Compare id.* § R18-5-234(A)(1)–(2), *with* § R9-8-803(E)(3), *and* § R9-8-803(A)(3).
88. *See, e.g.*, § R9-8-803(E)(3).
89. *Id.* § R18-5-234(F).

dry disinfectant standards,[90] and application of chemical feeders.[91] Interestingly, Title 18 does not require record keeping and makes no provision for disinfection inspections.[92]

Despite these shared disinfection standards, Title 18 differs from Title 9 because it addresses construction standards for pools and spas.[93] Title 18 lays out many important construction considerations, including how to get design approval ("submit an ADEQ application form to the Department in quadruplicate"),[94] acceptable construction materials ("concrete . . . fiberglass or acrylic"),[95] and the required shape,[96] lighting,[97] water depths,[98] lifeguard chairs,[99] number of entries and exits,[100] depth markers,[101] and rope and float lines.[102] These numerous and thorough design criteria apply to both public and semipublic swimming pools and spas.[103] Further, "[a] professional engineer, architect, or a swimming pool or spa contractor with a current A-9, A-19, KA-5, KA-6 license shall prepare or supervise the preparation of all plans and specifications submitted to the Department for review."[104]

Title 18 also includes a section governing wading pools.[105] Wading pools are defined as "a shallow swimming pool used for bathing and wading by small children."[106] A wading pool tops out at a maximum depth of two feet.[107] The regulation incorporates by reference all other "design criteria prescribed in [the] Article for public or semipublic pools[.]"[108] Presumably, this includes the litany of construction standards and the disinfection requirements as applicable to pools. The wading pool section does require operators to separate their equipment for water circulation from disinfection equipment,

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90. *Id.* § R18-5-234(G).
91. *Id.* § R18-5-234(H)–(I).
92. *See generally* ARIZ. ADMIN. CODE §§ R18-1 to -17 (missing information about disinfection quality control, standards and procedures for inspections, and many other gaps).
93. *See* ARIZ. ADMIN. CODE §§ R18-5-201 to -251 (2020).
94. *Id.* § R18-5-203(B).
95. *Id.* § R18-5-207(A).
96. *Id.* § R18-5-209.
97. *Id.* § R18-5-218.
98. *Id.* § R18-5-219.
99. *Id.* § R18-5-238.
100. *Id.* § R18-5-213.
101. *Id.* § R18-5-220.
102. *Id.* § R18-5-239.
103. *Id.* § R18-5-202(A).
104. *Id.* § R18-5-203(D).
105. *Id.* § R18-5-244.
106. *Id.* § R18-5-201.
107. *Id.* § R18-5-244(C).
108. *Id.* § R18-5-244(A).

and mandates a maximum turnover cycle of one hour.[109] Importantly, there can be no cross-connection between the water circulation system of a wading pool to that of a public or semipublic swimming pool.[110] Finally, the equipment must preserve uniform disinfectant residual throughout the wading pool.[111]

Applying these wading pool standards to splash pads reveals a critical regulatory gap. Splash pads do not meet the Title 18 definition of a wading pool. Though a splash pad would meet some of the design criteria—it certainly has a depth less than twenty-four inches[112]—many of the criteria are entirely inapplicable and somewhat outlandish, especially for the stand-alone splash pads pervasive throughout Phoenix. For example, if considered a wading pool, each public splash pad in any park would require "at least one elevated lifeguard chair" and at least "one ring buoy or a similar flotation device . . . attached to 50 feet of ¼ inch rope."[113] It is difficult to imagine a lifeguard chair and ring buoy next to the splash pad in the middle of a shopping center or in Central Phoenix's Civic Space Park. Because these safety criteria from the Title do not seem applicable to a splash pad, operators may not feel the need to comply with the other safety criteria—namely, the disinfection standards.

Perhaps splash pads are intended to fall under the definition of water fountain instead: "a bathing place that functions by using mechanical means to propel a stream of water out of an opening or structure."[114] But the only other reference to "water fountain" in Title 9 is to allow an operator to "draw water from a swimming pool for a water slide or a water fountain without filtering or disinfecting the water."[115]

C. Other Jurisdictions' Approach to Splash Pad Liability.

Several instances of PAM infection have resulted in settlements. The two boys from Tulsa, ages seven and nine, who contracted PAM from playing in a splash pad, settled with the city for a total compensatory award of $315,000.[116]

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109. *Id.* § R18-5-244(E).
110. *Id.*
111. *Id.* § R18-5-244(H).
112. *Id.* § R18-5-244(C).
113. *Id.* § R18-5-238(B).
114. *Id.* § R9-8-801(37).
115. *Id.* § R9-8-804(B).
116. Hampton v. City of Tulsa, 2007 WL 7552544 (Okl. Dist.); *see also* P.J. Lassek, *supra* note 30.

Other cases involving PAM infection are based on a theory of premises liability. In the summer of 2012, a thirty-year-old swimmer, Abel, contracted PAM while swimming in a lake in Indiana.[117] His estate filed a suit against the county, the Parks and Recreation Department, and the Health Department.[118] The estate relied upon a negligence theory of liability, arguing that the county was negligent for

> failing to protect the public from injury, including the Plaintiff, by failing to test the water of West Boggs Lake to determine the existence of harmful organisms in the water, including but not limited to *Naegleria fowlari* [sic], to properly maintain West Boggs Lake in a manner permitting safe swimming, and failing to warn the public of a dangerous condition at West Boggs Lake, including failing to warn the public of the existence of *Naegleria fowlari* [sic] in the water.[119]

The Indiana Court of Appeals took the case on interlocutory appeal to decide if the County owed a duty of care to the Plaintiff.[120] The Indiana Court of Appeals reviewed several premises liability cases and determined that the duty of care owed to a plaintiff "depend[s] on one critical element—foreseeability."[121] The court also adopted the Restatement (Second) of Torts definition of "a landowner's duty to an invitee for a condition of the land."[122] Under this analysis, a landowner is liable if he or she

> (a) knows or by the exercise of reasonable care would discover the condition, and should realize that it involves an unreasonable risk of harm to such invitees, and (b) should expect that they will not discover or realize the danger, or will fail to protect themselves against it, and (c) fails to exercise reasonable care to protect them against the danger.[123]

Ultimately, because there was no evidence that the County knew of the presence of the amoeba, and because "a PAM infection, especially in Indiana, is very rare," the court found that the County and Parks Board did not owe the plaintiff a duty of care.[124] Simply because it was not reasonably

117. Tim Evans, *Is Deadly Single-Cell Organism the Next Jaws?*, INDY STAR (June 22, 2017), https://www.indystar.com/story/news/2017/06/22/whos-blame-lakes-brain-eating-amoeba-appeals-court-wades-into-negligence-lawsuit/411223001/ [https://perma.cc/U8AU-8JVU].

118. Daviess-Martin Cty. Joint Parks & Recreation Dep't v. Estate of Abel by Abel, 77 N.E.3d 1280, 1282 (Ind. Ct. App. 2017).

119. *Id.* at 1283 (quoting Appellants' App. Vol. II at 25).

120. *Id.* at 1284.

121. *Id.* at 1286.

122. *Id.* at 1288.

123. *Id.*

124. *Id.* at 1289.

foreseeable that Abel would contract PAM infection, the court ruled against Abel and his family.[125] The court also considered the lack of a disinfection regime available for lake water and the lack of a rapid result test to show the presence of *N. fowleri* in their determination that a duty of care is not present, even though "the circumstances here were tragic."[126]

In another decision from 2017, the Court of Appeals of Minnesota also considered premises liability in a case where an individual was infected with PAM after swimming in a freshwater lake.[127] Nine-year-old Jack Ariola-Erenberg had contracted PAM from Lily Lake in Stillwater, Minnesota in 2012.[128] Lily Lake is partially fed by untreated storm water run-off through a number of pipes installed by the city.[129] One such pipe is located within one hundred feet of the public swimming area.[130] This case differed from the Indiana case primarily because it was well-known that the storm water run-off contained polluted water; for years, a citizen's group complained about the water quality and "started a campaign to improve . . . water quality and to raise[] awareness that storm-water runoff polluted Lily Lake."[131] The city began steps to improve the lake's water quality, but it only completed one of the three critical steps it identified and outlined.[132]

Two years before Jack's infection, a seven-year-old Stillwater girl died from PAM after swimming in Lily Lake.[133] Her death was surrounded by a media flurry, and an investigation by the Minnesota Department of Health and the Centers for Disease Control and Prevention revealed that Lily Lake water and sediment samples tested positive for *N. fowleri*.[134] After her death, Lily Lake remained open to the public for swimming, with a sign warning of the risk of swimming without a lifeguard on duty, but no sign describing the risk of amoeba infection.[135] Each subsequent year, including the year of Jack's death, the CDC took samples of Lily Lake and each time determined that the samples contained the deadly amoeba.[136] However, at the time of Jack's estate's lawsuit, three city officials testified that "before Jack's death, they were unaware that [the previous swimmer] had died from NF after

125. *Id.* at 1290.
126. *Id.*
127. Ariola v. City of Stillwater, 889 N.W.2d 340, 341 (Minn. Ct. App. 2017).
128. *Id.* at 344.
129. *Id.*
130. *Id.*
131. *Id.*
132. *Id.*
133. *Id.* at 344–45.
134. *Id.* at 345.
135. *Id.* at 346.
136. *Id.* at 345.

swimming in Lily Lake, that Lily Lake contained a dangerous substance, or that the county, MDH, and CDC had taken samples from Lily Lake for testing."[137] Finally, after Jack's death in 2012, Lily Lake was closed.[138]

Despite the history of PAM and Lily Lake, the Court of Appeals of Minnesota still found that the City of Stillwater was not liable under the theory of "recreational-use immunity" because there was no evidence that "the city had actual knowledge of an artificial condition likely to cause death or serious bodily harm."[139] Here, the court decisively ruled that the City must have actual knowledge of the dangerous condition in order to bypass recreational-use immunity.[140] Despite the overwhelming media attention following the death of the seven-year-old girl in 2010 and the County's positive *N. fowleri* tests in 2010 and 2011, the court ruled that the City lacked actual knowledge of the amoeba.[141] Further, the court denied Jack's theories of willful blindness and implied notice to satisfy the duty requirement.[142] As such, even though the result was "heartbreaking," the Court of Appeal's decision had "the cumulative effect of denying relief for Jack's estate."[143]

Each instance of PAM infection in the United States is followed by a flurry of public outcry.[144] Sometimes, this outcry can lead to positive change. After the two deaths in Tulsa, operators decided to review existing and new splash pads to ensure the safety of their citizens.[145] Now, city park officials inspect each of the thirty splash pads and water playgrounds at least once a week.[146]

Even a judge on the Indiana Court of Appeals, while agreeing that the County should not be liable, wrote that, because the knowledge of the amoeba's presence in warm freshwater lakes has been known for five decades, "owners and operators of freshwater recreational areas do have a duty to know about the amoeba; the harm it can cause; and the options for

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137. *Id.* at 346.
138. *Id.*
139. *Id.* at 361.
140. *Id.* at 355.
141. *Id.* at 358.
142. *Id.* at 359.
143. *Id.* at 360.
144. Richard Knox, *Deadly Amoeba Found for First Time in Municipal Water Supply*, NPR (Sept. 15, 2013, 8:02 AM), https://www.npr.org/sections/health-shots/2013/09/15/222197599/deadly-amoeba-found-for-first-time-in-municipal-water-supply [https://perma.cc/NB8D-F8PK] ("'In the old days, you would look at your faucet and it wouldn't scare you,' [Louisiana state epidemiology Raoult] Ratard says. 'But these days, for some people, it looks menacing.'").
145. Michelle Linn, *How Safe Are Tulsa's Splash Pads?*, FOX 23 NEWS (July 18, 2016, 11:05 PM), https://www.fox23.com/news/how-safe-are-tulsas-splash-pads/406186375/ [https://perma.cc/8VLT-DB38].
146. *Id.*

and efficacy of testing, treatment, and warnings to users."[147] "[T]he ubiquitous nature of the amoeba" should put the Indiana county "on notice that it was most likely present" thus satisfying the foreseeability requirement.[148]

D. Model Codes Governing Splash Pads.

The Center for Disease Control promulgates the Model Aquatic Health Code (MAHC). It is the result of a seven-year collaboration between "public health, academic and aquatics industry representatives across the United States on guidance to prevent drowning, injuries and the spread of recreational water illnesses at public swimming pools and spas."[149] The CDC released the third edition of the MAHC in July of 2018.[150] This hefty document contains model regulations covering a wide range of subjects including design and construction, lifeguard training, recirculation and filtration, injury prevention, and disinfection.[151]

The MAHC explicitly mentions the term "splash pad."[152] It is included under the broader definition of *interactive water play aquatic venue*, which means "any indoor or outdoor installation that includes sprayed, jetted or other water sources contacting bathers and not incorporating standing or captured water as part of the bather activity area . . .[t]hese aquatic venues are also known as splash pads, spray pads, wet decks."[153] The MAHC is explicit in stating that these interactive water play venues must comply with "the general aquatic venue requirements stated in this Code."[154] The MAHC has strict chloride demand factors to determine the amount of chlorine disinfection needed for all aquatic venues, including the surface area, volume, type of venue, hours of UV exposure, water temperature, and anticipated exposure to vegetation.[155]

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147. Daviess-Martin Cty. Joint Parks & Recreation Dep't v. Estate of Abel by Abel, 77 N.E.3d 1280, 1291 (Ind. Ct. App.) (Robb, J., concurring).

148. *Id.*

149. *CDC's Model Aquatic Health Code (MAHC)*, WORLD WATERPARK ASS'N, https://www.waterparks.org/web/Tagged_Content/Hot_Topics/MAHC.aspx [https://perma.cc/NUC6-92M3].

150. MODEL AQUATIC HEALTH CODE (CTRS. FOR DISEASE CONTROL & PREVENTION 2018).

151. *Id.*

152. *Id.* § 3.2.

153. *Id.*

154. *Id.* § 4.12.8.1.

155. *Id.* § 4.7.3.2.2.2.1.

A competing code is promulgated by the Association of Pool and Spa Professionals (APSP) and the National Swimming Pool Foundation.[156] The competing code is the International Swimming Pool and Spa Code (ISPSC), which was written by their industry professionals, and had been adopted by eight Arizona counties as of fall 2017.[157] Arizona is currently a battle ground state between these two codes, as evidenced by a clash in August of 2017 where executives of both the CDC and the APSP traveled to Arizona to advocate for their respective codes.[158]

In a statement submitted to the Arizona Department of Environmental Quality, APSP "acknowledges that the MAHC offers many benefits in the area of pool operation and maintenance, such as water quality and use of chemicals, areas which are well within the expertise of the CDC."[159] But, the codes differ sharply on construction specifications and requirements.[160] The ISPSC does not explicitly define splash pad.[161] It does define interactive play attraction as a "water play device" with varied hydraulic capabilities—which could include splash pad water fountains—but goes on to provide examples such as "slides, climbing and crawling structures," which calls to mind far more complex water playgrounds than the typical, traditional concrete splash pad with a few shooting jets.[162]

II. ANALYSIS

The current bifurcated Arizona code is ineffective at preventing *N. fowleri* infections. Simple measures, such as chlorination, filtration, and well-constructed pipes and barriers have been shown to reduce the risk of infection by staggering amounts.[163] However, Arizona's current code falls short of protecting its citizens.

Arizona could take several approaches to change its water quality regulations. This Comment argues that the best solution is a hybrid of several

156. Robledo, *supra* note 66.

157. *Id.*

158. *Id.*

159. *Id.*

160. *Id.*

161. *See* International Swimming Pool and Spa Code § 202 (2018), https://codes.iccsafe.org/content/ISPSC2018/chapter-2-definitions [https://perma.cc/4R8L-66GA].

162. *Id.*

163. *See Parasites*—Naegleria fowleri—*Primary Amebic Meningoencephalitis (PAM)—Amebic Encephalitis: Pathogen & Environment*, CTRS. FOR DISEASE CONTROL AND PREVENTION, https://www.cdc.gov/parasites/naegleria/pathogen.html [https://perma.cc/9FMV-G6X9].

of these methods, combining new water quality standards with construction standards, regular inspections, and a public outreach campaign. A menu of options, and their singular deficiencies, is set forth below.

A. Arizona's Current Standards Fail To Eliminate the Amoeba Threat.

The only true safety measure in the current Administrative Code is the water disinfection standard.[164] This standard allows the pool operator to choose between a free chlorine residual between 1.0 and 3.0 parts per million, or an alternative method of disinfection—either a free bromine residual level or a certain oxidation-reduction potential.[165]

N. fowleri exhibits moderate susceptibility to disinfection by chlorination.[166] In controlled laboratory conditions, a chlorine concentration of one part per million (one milligram per liter) reduced the number of viable *N. fowleri* cysts by 99.99% in a clear sample of water in about an hour.[167]

However, in real-life applications, this chlorine level may not be sufficient to effectively kill the amoeba, particularly if the water is murky.[168] In particular, pipes with biofilms could protect the *N. fowleri* from chlorine disinfectants.[169] One recent study revealed that in the presence of a natural biofilm, the amoeba can survive for three hours in a chlorine dose as high as twenty milligrams per liter.[170] Similarly problematic, *N. fowleri* especially thrives in warm water, growing best at higher temperatures.[171] Studies have not yet found if a chlorine concentration of one part per million is equally effective at all temperatures.

Arizona's chlorine standard, one part per million, would be sufficient in a laboratory condition. But this standard fails to take the existence of biofilms

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164. ARIZ. ADMIN. CODE § R9-8-803(D) (2019).

165. *Id.*

166. *Parasites*—Naegleria fowleri—*Primary Amebic Meningoencephalitis (PAM)—Amebic Encephalitis: Pathogen & Environment*, *supra* note 163.

167. *Id.* It is unclear whether this figure includes the number of viable amoebae in other stages.

168. *Chlorination, Filtration Systems Failed To Kill Brain-Eating Amoeba that Killed U.S. Teen*, ASSOCIATED PRESS (July 1, 2016, 6:41 PM), https://www.ctvnews.ca/health/chlorination-filtration-systems-failed-to-kill-brain-eating-amoeba-that-killed-u-s-teen-1.2970019 [https://perma.cc/F2GL-QBYE].

169. Janet Pelley, *"Brain-Eating Amoeba" Scoffs at Chlorine in Water Pipes*, CHEMICAL & ENGINEERING NEWS (Sept. 2, 2015), https://cen.acs.org/articles/93/web/2015/09/Brain-Eating-AmoebaScoffs-Chlorine-Water.html [https://perma.cc/3BJ4-7ULY].

170. *Id.* Biofilm absorbs free chlorine, reducing the concentration of chlorine available to kill amoeba. *Id.*

171. *Parasites*—Naegleria fowleri—*Primary Amebic Meningoencephalitis (PAM)—Amebic Encephalitis: Pathogen & Environment*, *supra* note 163.

into account. An actually effective range for killing amoeba should be much higher.[172] The current Arizona standard barely scrapes the surface of an acceptable amoeba-killing range.

As to Arizona's alternatives for water disinfection (free bromine or reduction oxidation potential), no studies have been done to directly measure their effectiveness at eliminating *N. fowleri*.[173] Perhaps the one part per million concentration of bromine needs to be increased significantly, like the chlorine, but scientific reports do not yet lead to a clear conclusion. Likewise, similar studies have not been completed for *N. fowleri* and reduction oxidation potential variant disinfection. Further complicating the problem, Arizona's hot weather raises ground temperatures and the average temperature of water in pipes. Not only does this provide a favorable environment for the amoeba to flourish, it also encourages the growth of biofilm, rendering free chlorine more and more useless.

Further, as stated above, it is not even clear that these standards apply to splash pads at all. Splash pads could be defined as a wading pool or a water fountain.[174] Water quality standards for water fountains are never spelled out. So, operators of splash pads could, within the bounds of the rule, not chlorinate their water *at all*. Splash pads in Arizona could feasibly be fed with tap water and still be within the bounds of the law—a dangerous situation.

PAM infections are devastating for families and communities. Arizona's warm climate puts its populations at particular risk. Arizona has a number of different options as it considers changing its water quality standards, including the do-nothing approach, the premises liability approach, revising the administrative code, or alternative fixes.

B. The Do-Nothing Approach Puts Children in Danger.

Arizona could choose to leave the administrative code governing water quality as-is, making no changes.[175] The number of deaths in Arizona due to *N. fowleri* infection is low compared to other diseases, so the legislature could choose to focus resources and energy on other issues that impact a larger swath of the population.

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172. *See* Pelley, *supra* note 169.

173. *See* NAT'L RESEARCH COUNCIL (US) SAFE DRINKING WATER COMM., DRINKING WATER AND HEALTH: VOLUME 2 79–80 (1980), https://www.ncbi.nlm.nih.gov/books/NBK234590/ [https://perma.cc/KP2X-6UM4] (describing bromine's effectiveness at killing a different amoeba, *Entamoeba histolytica*).

174. *See supra* discussion at Part I.B.2.

175. Proposed water quality regulation updates from 2017 died in committee. *See* 23 Ariz. Admin. Reg. 1883 (July 14, 2017).

This is the most cost-efficient option, as it imposes no further costs on the state. Similarly, none of the splash pad operators need to change their processes nor designs. Splash pad operators will not need to construct additional barriers, retrofit pipes or filters with new equipment, and chlorine consumption remains the same. Inspections, if there are any, can continue on their normal schedule. If there is no change in chlorination standards, there is no change in the environmental impact of splash pads, so there is no need for environmental impact studies. Municipalities can continue their loose monitoring of fountains, requiring a building permit but nothing more.

This approach, though low cost, fails to take into account the value of human lives. Children will continue to get sick at the same or higher rates as before. As splash pads age, their biofilms will grow, and the already-ineffective chlorine will become even less effective. As the concrete pads age underneath the splash pads, their bases will crack, allowing in more dirt and debris, all which carry the amoeba in its encysted form.

This approach is the wrong one to take. Instances of PAM infection can be eliminated or reduced with relative simplicity, and Arizona has the opportunity to do so as it updates its water quality regulations.

C. The Premises Liability Approach, Though Economically Rational, Is Not Viable in the Long-Term.

PAM infections are currently treated as a lightning strike—rare and unfortunate, with no liability to assign. Who should bear the burden of this devastating disease? Tort law answers the question after infection, and most likely places the burden on the deceased children and their families.

Liability could be assigned to the operator of the splash pad, either private or public. However, the rarity of this disease makes the Plaintiff's burden of proof on foreseeability of the harm impossible to meet. In *Ariola v. City of Stillwater*, despite two deaths from amoeba contracted from the same lake, the court held that the risk of harm was so unforeseeable, liability could not be imposed.[176]

From a purely economic perspective, perhaps premises liability is a reasonable solution. Assuming that Plaintiffs rarely carry the burden of proof in a PAM case, the number of instances where a governmental agency or private pool operator must pay will be very low. The difficulty of proving negligence will keep settlement amounts low, even though the victims are typically children. The City of Tulsa settled for only $315,000 for the death

176. *See* Ariola v. City of Stillwater, 889 N.W.2d 340, 342 (Minn. Ct. App. 2017).

of two young boys.[177] Letting these cases settle or go to trial is perhaps the path of least resistance.

However, imposing premise liability is not a good economic option for the long term. Rapid detection tests for the presence of *N. fowleri* are on the rise.[178] If detected and treated within a short time period after the initial onset, patients can actually survive PAM. However, patients frequently sustain brain damage. Because the amoeba is literally eating brain matter as it grows, patients are racing the clock to get treatment to preserve their cognitive functioning. Depending on how and when the doctors administer the antibiotic, the patient can either make a full recovery or have permanent brain damage.[179] Permanently brain-damaged children can present huge damages, including monetary compensation to pay for lifelong medical care. This would certainly drive up the average settlement amount. Furthering the problem, recent studies hypothesize that the actual number of PAM deaths is much higher than the average reported by the CDC each year. Because so many instances of PAM go undiagnosed, the CDC's estimate of three deaths per year is hypothesized to be six times too low.[180]

Another form of liability to consider is medical malpractice liability. As the treatment for PAM becomes more accepted in the medical community,[181] but the disease remains rare, doctors will be held to a standard of reasonable recognition of the signs and symptoms of PAM. As such, imposing liability is economically sound in the short run, but not in the long run.

177. Hampton v. City of Tulsa, JVR No. 1102230108, 2007 WL 7552544 (Okla. Dist. Feb. 14, 2007).

178. *See generally* Zhihao Yu et al., *Application of Untargeted Metabolomics for the Detection of Pathogenic* Naegleria Fowleri *in an Operational Drinking Water Distribution System*, 145 WATER RESEARCH 678, 678 (2018).

179. W. Matthew Linam et al., *Successful Treatment of an Adolescent with Naegleria Fowleri Primary Amebic Meningoencephalitis*, 135 PEDIATRICS e744–e748 (2015), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4634363/ [https://perma.cc/Z2TX-XUY5] (documenting the case of a 12-year-old girl who contracted PAM and returned to normal brain functioning 6 months after the full course of treatment).

180. Matanock et al., *supra* note 9.

181. *See* Linam et al., *supra* note 179 (documenting the third survivor of PAM in North America in 2013).

D. Alterative Fixes Would Have Smaller Environmental Impact but Are Least Effective.

1. Filtration

As an alternative to chlorine, filtration provides a way to eliminate amoeba from a water supply. Water can be sterilized by pouring it through a filter with an absolute pore size of less than one micron.[182] Disinfection via this method has many environmental benefits. Excess chlorine will not be introduced into any open water systems that birds or bugs can access. It will also mitigate the skin and eye irritation caused by chlorine.

However, one-micron filters are expensive to purchase on a scale large enough to supply a splash pad. Also, these fine filters require regular upkeep and replacement to unclog and insure smooth operation. Further, filtered water does not have the same anti-microbial properties as chlorinated water. Filtered water is only pure and disinfected the second it streams out of the filter. As children splash and play, introducing dirt and mud into the system, the amoeba can be rehydrated and thrive in the now-contaminated water.

2. Construction

Another proposed solution to the problem is to completely isolate the splash pad from any organic material that may introduce the amoeba into the system. The Tulsa boys contracted PAM from creating their own slip 'n slide using splash pad water and a nearby patch of grass. As they slid on their bellies in the grass, the amoeba from the dirt mixed with the splash pad water and shot straight up their noses. Infection occurred within two days.[183]

The theory behind the construction standard method is that concrete barriers will create a fence that keeps the amoeba at bay. By separating the amoeba and the water, the infection cannot spread. This method only works if the water coming out of the pipes is clean. Even though this method eliminates the risk of infection via rehydration, the original risk of infection via the municipal water system still exists. This solution also assumes that

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182. Jennifer R. Cope et al., *The First Association of Primary Amebic Meningoencephalitis Death with Culturable* Naegleria Fowleri *in Tap Water from a U.S. Treated Public Drinking Water System*, 60(8) CLINICAL INFECTIOUS DISEASES e36–e42 (2015), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4627687/ [https://perma.cc/2C4Y-BTKS]. For context, a coffee filter has a pore size of 20 microns.

183. Professor Marsha Howard, a former professor of the Author, discussed this information with the boys' families.

every child walking into the splash pad to play is clean and free of mud, dirt, or sand.

The construction solution is unique in that it is somewhat effective at a low cost. The burden of this solution falls on the constructors of the splash pad, not the operator and not the government. Similarly, inspection needs to only happen once to verify that the concrete barrier is in place. No regular inspections after that are necessary.

E. Hefty Changes to the Model Codes Must Be Implemented To Make Them Workable.

Arizona could change the current administrative code or adopt either the Model Aquatic Code or the International Swimming Pool and Spa Code. Regardless of which statutory route Arizona decides to take, the bifurcated regime between the two departments that currently regulate this area should end. Ownership of water quality regulations by one department would streamline administration by closing current gaps, such as the lack of an express definition of "splash pad" and the uncertainty of whether a splash pad is covered by either set of rules. Similarly, redundancies in the code could be fixed if one department wholly owned governance of pools, spas, fountains, and splash pads. Currently, for example, chlorine standards are located in two different titles in the Arizona Administrative Code. Consolidation into one title could streamline implementation for owners and operators and help maintain an efficient inspection regime.

Additionally, Arizona needs to create and maintain a register of all splash pads in the state. Each city and county issues construction permits, but the state entities do not seem to track splash pads. A registry of splash pads would allow Department of Environmental Quality employees to survey, sample, and inspect splash pads for compliance. A registry of this sort should also show what water source each splash pad draws from. An integrated diagram showing sources and splash pads could prove to be invaluable in case of an infection. In that situation, the Department of Environmental Quality could easily determine which splash pads share a water source with the pad that caused the infection. Then, all pads in that zone could be turned off, stymying the spread of infection between pads or neighborhoods, until the amoeba is eradicated.

Adoption of a statutory regime that expressly defines splash pads and sets standards for chlorination is a step in the right direction. Chlorinated water has anti-microbial properties that encompass not just amoeba, but other more

common waterborne pathogens as well.[184] Chlorine should be adopted as the one and only standard for water disinfection in splash pads until the efficacy of free bromine residuals and oxidation reduction potentials are better understood.

Finally, the age and operation of each splash pad should be monitored to keep track of necessary maintenance. The presence of a biofilm should be closely monitored and eliminated once it reaches a dangerous threshold. The legislature should apportion money each year for maintenance and flushing of the entire water system of each municipality.

F. The Best Solution Combines New Regulations, Inspections, and Social Outreach.

Though each of the potential solutions has drawbacks and costs, the cost of human life due to a preventable disease is the greatest cost of all. The weak and disjointed approach that Arizona has taken to water disinfection standards leaves us vulnerable to infection. The time has come to change Arizona's splash pad water quality governance.

First and foremost, "splash pad" must be clearly defined in the regulations. A definition wholly separate from both wading pool and water fountain, designed to capture splash pads of all construction, is the first step in any water quality reform effort.

Second, adoption of a uniform free chlorine concentration is imperative. By eliminating alternative methods of disinfection (bromine and oxidation reduction) and combining chlorination levels under one single title of the Arizona Administrative Code, implementation will be streamlined. Though the one part per million (one milligram per liter) dose of chlorine is effective at preventing *N. fowleri* growth, a truly effective system eliminates organic sediments, and uses secondary disinfection mechanisms, such as ultraviolet light or filtration, to ensure an even distribution of chlorine.[185]

Additional measures for ensuring splash pad safety stem from construction and registration. All splash pads should be registered in case of outbreak and to create an efficient inspection process. All splash pads must

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184. For a description of common waterborne diseases, *see Common Waterborne Disease, Bacteria, Viruses and Cysts*, GLOBAL HYDRATION (2018), https://globalhydration.com/waterborne-disease/common-waterborne-disease-bacteria-viruses-cysts/ [https://perma.cc/EF9H-MUDK].

185. *Parasites*—Naegleria fowleri—*Primary Amebic Meningoencephalitis (PAM)—Amebic Encephalitis: Pathogen & Environment*, *supra* note 163; *see also Reducing the Risk of* Naegleria Fowleri *with CLEAN-FLO*, Clean-Flo https://www.clean-flo.com/naegleria-fowleri/ [https://perma.cc/MQA5-FR6P]

comply with construction standards that include a small concrete barrier to prevent the introduction of organic matter into the play area.

Implementation of a structured inspection regime will ensure compliance with these changes. Inspectors should visit splash pads several times over the course of the year to get readings in both warm and cooler seasons. Free chlorine levels should be measured, and as rapid detection kits for amoeba begin to be massed-produced, amoeba levels should be checked. A visual inspection of the pad might reveal cracks, mud, or other organic materials that could be a source of encysted amoeba into the system. Biofilm levels in pipes feeding the splash pads should likewise be checked.

Finally, and importantly, this is a vital topic that is deserving of more attention in Arizona. At minimum, splash pad operators should be required to post the water source that feeds their splash pad to provide parents notice of whether the water is chlorinated or merely tap water. Additionally, parents should be educated to recognize the signs of an amoebic infection and know when to take their children to the emergency room. If a child contracts PAM, the first few hours after the onset of symptoms are critical. Doctors should be educated on this rare disease and know which cerebral spinal fluid tests to perform to quickly make a diagnosis. All hospitals should stock amphotericin B deoxycholate, the life-saving drug that can stop an amoeba in its tracks.

On the prevention side, splash pad operators should be made aware of this life-threatening risk. Parents should be educated to give their young children nose plugs, not use tap water in Neti pots, and avoid splashing in muddy water.

III. CONCLUSION

PAM is considered a "lightning strike" disease, but a recent estimate has actual occurrences of PAM as much higher—as many as nineteen deaths per year.[186] Many other types of water-borne pathogens could be treated with chlorination as well, including *E. coli*, *Shigella,* and *Cryptosporidium*, and other species of pathogenic amoeba.[187] Changing Arizona's water quality regulations is an easy and cost-effective method of preventing PAM and other

186. Matanock et al., *supra* note 9. Interestingly, lightning killed 20 U.S. citizens in 2018 and nearly matched the hypothesized death toll of *N. fowleri* in 2017, which was 19. *U.S. Lightning Deaths in 2019: 20***, NATIONAL WEATHER SERVICE, https://www.weather.gov/safety/lightning-fatalities [https://perma.cc/4B8F-743J]. When deaths from *N. fowleri* are combined with deaths from the other species of pathogenic amoeba, that number far exceeds lightning strike deaths in the U.S. *Id.*

187. Daniel S. Graciaa et al., *Outbreaks Associated with Untreated Recreational Water—United States, 2000–2014*, MORBIDITY & MORTALITY WKLY. REP. (June 29, 2018), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6023190/ [https://perma.cc/A2G7-JBQ3]

diseases. The do-nothing approach to this danger is entirely ineffective; it is an unnecessary risk that could be easily mitigated. Water quality regulations are a net good and extend a benefit beyond a potential amoeba infection.

Arizona can further ensure children's safety in water recreation through more frequent inspections of not just splash pads, but swimming pools, lakes, municipal drinking water supplies, and other freshwater recreational sites. Similarly, increased penalties for disinfection non-compliance, and greater liability for swimming pool operators who *should* know about this risk, may help diminish the risk of infection. Finally, the Arizona Department of Health Services should educate parents and doctors about the rare symptoms of PAM infection.