

## **A Call to Action: What Physicians Need to Know about Water Beads**

Are Water Beads Toxic? Yes, water beads can be toxic. 'Non-toxic' labeling can mislead.

Play is the occupation of childhood, toys are the tools and materials of the trade. Alice Hamilton wrote in her book, *Exploring The Dangerous Trades* "...what we should never forget, that even with all the help the laboratories can give us, it still remains true that for most of our knowledge concerning new compounds in industry we must depend on human experiments, the workman himself is the guinea pig". To better prevent, identify, and protect children from potential risks posed by toy products, physicians and researchers must view children as a unique class of workman. Despite the fact that children are not merely miniature adults, and have certain distinct vulnerabilities, the value of occupational medicine perspectives, literature, and expertise can not be overemphasized when assessing potential toy related hazards, and analyzing cases of real world harm associated with play, the pediatric occupation. Unfortunately, most medical students, residents, and practicing physicians have limited knowledge of Occupational Environmental Medicine (OEM). "Many physicians are unaware of OEM until after years of practice in another field" (Green-McKenzie et al., 2022). What physicians need to know about water beads highlights the importance of OEM training as well as the disastrous consequences and missed connections that occur when physicians and researchers lack OEM education.

Originally used for industrial purposes, recently water beads have been heavily marketed as a "non-toxic" sensory toy for children and as ammunition for a new type of toy gun. Water beads are sold under a variety of brand names. The beads are often imported and sold as both an agricultural soil conditioner and as a toy for children without the chemical ingredients and composition listed on the product's label. Water beads/ Super absorbent polymer balls are designed to absorb water, expand in size and volume, and are most often made of polyacrylamide-polyacrylate (Han et al., 2021). Polyacrylamide has a longer life span and is cheaper compared to potassium polyacrylate and sodium polyacrylate (IvyPanda, 2020). Polyacrylamide is considered non-toxic; however, it is made from the polymerization of neurotoxic acrylamide. "Polymerization reactions are rarely complete and therefore residual monomers might still be present in plastics..." (Zimmermann et al., 2022). "Depending on the polymer type, the polymerization process, and the technique used for reducing residual monomer content, monomers can still account for up to 4% by weight in the final material" (Zimmermann et al., 2022). According to the Albert Einstein College of Medicine, polymerized acrylamide gels should be treated with the same caution as acrylamide monomers themselves to avoid repeated accidental exposure to neurotoxic acrylamide monomers (Environmental health & safety: Acrylamide, n.d.). Polyacrylamide solid gels, such as water beads, can contain residual and extremely toxic acrylamide monomers in concentrations of 10-30% (Chen, 1979). Although water bead toys meet current CPSIA standards for heavy metal and phthalate levels, each batch and bag of beads is not required to be pre-tested for monomer concentration levels before being placed in commerce.

Acrylamide monomers are easily absorbed into an organism's circulatory system from dermal exposure, inhalation, and ingestion (Murray, 1996). Polyacrylamide for agricultural purposes is legally permitted to contain a residual level of acrylamide thousands of times greater in

concentration than polyacrylamide used in cosmetic formulations and water treatment for drinking water; 500 ppm for agricultural purposes, 0.1 to 0.5ppm for cosmetics, and the residual acrylamide limit for water suppliers by the EPA is less than 0.5 ppb (Chalker-Scott, 2007; Center for Science in the Public Interest, 2003). Manufacturers are not required to disclose the initial concentration of acrylamide monomer used to create their polyacrylamide or the amount of residual acrylamide monomer remaining after polymerization in any polyacrylamide-copolymer contained in toy products.

When ingestion of water beads is suspected, a high degree of suspicion is necessary. The beads do not behave as traditional foreign bodies due to their size and chemical composition. The chemical composition of the beads is generally unknown to physicians at the point of care and consumers at the point of purchase. Consumption and aspiration of water beads pose a public health risk, and the public should be informed of the dangers (Faytrouni et al., 2021). "Although acrylamide loses some toxicity after polymerization, it can still cause chemical corrosion of the nasal mucosa and can enter the digestive and respiratory tracts, where it is absorbed, entering the systemic circulation and causing toxic reactions" (Han et al., 2021). "Increased oral exposure to acrylamide impairs gastric emptying, intestinal motility, mucus secretion and compromises digestive and absorptive functions of the small intestines, especially the duodenum. These observations may be ascribed to acrylamide-induced impaired neuronal signaling, autonomic neuropathy, oxidative stress, inflammation and cell necrosis" (Ige et al., 2021). Additionally, the reduction in gastric protective factors caused by acrylamide exposure also contributes to the dose-dependent degeneration of gastric mucosal integrity, putting the patient's mucosa at risk for erosions and lesions (Ige et al., 2019).

"Duplicate cysts, alimentary tract duplications, are congenital lesions of the gastrointestinal tract." (Anand & Aleem, 2022) What we know from gastrointestinal, pharmaceutical, and medical device research is that the most prominent strategies for achieving gastric retention are density mismatching, geometry-based, and bioadhesive doses. (Laulicht et al., 2010) (Talukder & Fassihi, 2004) Water beads can operate as duplicate cyst type lesions along the gastrointestinal tract and achieve gastric retention because of their inherent swelling behavior, ability to collect together and modify geometric shape, density mismatching, and mucoadhesive yet corrosive chemical nature.

Water beads are banned in Italy and Malaysia because they are a safety hazard. Water beads should not be marketed to children and their families as toys, sensory toys, or therapeutic aids. Because "non-toxic" is not a regulated term, "non-toxic" claims on a product's label or online listing should not be solely relied upon to eliminate poisoning or chemical exposure from the initial diagnostic assessment or the formation of differential diagnoses.

### **Latest Research Information**

- Ingestion of water beads requires prompt medical attention and evaluation. Diagnosis is made more complicated due to imaging difficulties. (Faytrouni et al., 2021; Caré et al., 2021)
- Prompt endoscopic removal should be attempted for all patients with no signs of obstruction whenever the gel beads might be in the upper GI tract (Faytrouni et al., 2021).
- Case management should not conform to standard protocols of foreign body removal, and early removal whenever possible should be attempted to prevent complications such as obstruction, lung injuries, exposure to toxic chemicals specifically, extremely neurotoxic acrylamide, nasal cavity injuries, hearing loss, seizures, brain injury such as cytotoxic edema & encephalopathy, infection, sepsis and death (Faytrouni et al., 2021; Han et al., 2021).
- Water beads can remain in the respiratory tract undetected, a boy was diagnosed with focal lung bronchiectasis in the left lower lobe, which occurred after the patient aspirated a water bead the year before. The bead was removed using flexible bronchoscopy and a retrieval basket (Alharbi & Dabbour, 2020).
- A high degree of suspicion is necessary for prompt diagnosis due to imaging difficulties, beads may mimic duplicated cysts versus presenting as a traditional foreign body (Mullens et al., 2021).
- Duplicate cysts are congenital GI tract alignment abnormalities. Duplicate cyst structure can be divided into cystic or tubular on the basis of their structure. Research indicates identification of duplicated cysts is best assessed using ultrasound (Sangüesa Nebot et al., 2018; Di Serafino et al., 2015).
- Due to the ability of water bead material to mimic duplicated cysts, imaging utilized to identify duplicate cyst lesion pathology, ultrasound, should be utilized during assessment for potential water bead ingestions. Medical professionals should be aware ultrasound may underestimate the number of water beads when compared to endoscopic evaluation (Kim et al., 2020).
- Water beads can collect, forming a bezoar, asymptotically in the GI tract without belly distention or traditional GI symptoms of distress. (Faytrouni et al., 2021; Alharbi & Dabbour, 2020).
- Surgical management with complete removal of hydrogel granules from the gastrointestinal tract is required, when the child presents to hospital with intestinal obstruction symptoms and surgeons must be aware the beads have the ability to collect lower in the GI tract and form a new mass if all beads are not removed. Surgeons should also be aware ultrasound can miss beads lower in the digestive tract (Shangareeva et al., 2019).
- Pediatric patients who are young or non-verbal cannot be relied upon to effectively and consistently communicate pain. Furthermore, “Pediatric patients are not reliable historians and events are not typically witnessed” (Sterling et al., 2016)
- Age restriction and parent observation are not an effective way to prevent water bead ingestions from occurring, as nearly half of the reported incidents occurred in school-aged children, with 30% occurring while the children were at school (Alharbi & Dabbour., 2020).

- Symptoms of pain or distress may be less obvious to those outside the immediate household and include increased night wakings, increased fussiness and irritability.
- If enterotomy is performed look for signs of edematous and swollen bowel mucosa. Water Beads can form thick sludge and cause obstruction. Even if the bowel looks healthy, there is a danger of anastomotic leak and intestinal compromise which can result in severe complications including infection, septicemia, and death (Mirza & Sheikh 2012).

Cases presenting with a dermatitis rash on the mouth and/or hands should be handled very carefully. The presence of a dermatitis rash should alert clinicians to the possibility the patient has suffered a higher level of acrylamide dose exposure. Do not dismiss the possibility of neurological damage because the patient did not lose consciousness. Specific clinical features of acrylamide intoxication are more conclusive than electrophysiological and biochemical laboratory tests for diagnosis. Patients, especially ones with the rash should be monitored for follow-up care and closely monitored for any signs of regression or neurological involvement. Referral to the developmental pediatrician, neurology, and ECI may be needed. A patient's clinical history is often the cornerstone of diagnosis in neurotoxicology. Tests to identify exposure to acrylamide are not readily and widely available to clinicians: laboratory studies are unhelpful, evidence of peripheral neuropathy on nerve conduction studies supports the diagnosis of acrylamide neurotoxicity, normal studies do not exclude the diagnosis. (Murray, 1996). Data on the residual monomer content of acrylamide in polyacrylamide is scarce; it is difficult to analyze acrylamide in solid materials; and chemical analysis is difficult owing to interference concerns. As a result, accurate measurement of acrylamide content at the analysis is unlikely. (Poulsen, 2019), (*Acrylamide - health effects, n.d.*). (*Acrylamide (PIM 652). n.d.*). (*Public health statement acrylamide - agency for toxic..., 2012*). (*Acrylamide EHC 49, 1985*)

Toxicity symptoms in pediatric patients particularly, when the water bead ingestion timeframe is unknown, include:

- Dermatitis rash
- Rhinorrhoea
- Seizures
- GI symptoms such as constipation and/or diarrhea; Projectile vomiting and other traditional obvious obstruction symptoms appear after the rash and can be delayed for long periods after initial ingestion due to beads not consistently traveling through the digestive tract
- Pediatric patients can be clingy to caregivers
- Increased need to nurse
- Weight loss with normal appetite
- Signs and symptoms of motor and sensory peripheral neuropathy
- Cytotoxic edema / cellular edema, seeming to mimic an acute ischemic stroke (EEG may be abnormal when beads are in patient according to one case study [not enough evidence to definitively say if all cases will present this way], CT scan and MRI are

normal; according to radiopaedia, MRI with diffuse weighted imaging is able to identify cytotoxic edema) (Goel & Bell, 2013)

- Toxic Brain Encephalopathy

“Non-toxic” has a specific connotation; for most people it means safe, pure, and not hazardous. Merriam Webster defines the term “non-toxic” straightforwardly as, not toxic. Many consumers are under the impression that when a product is labeled non-toxic it means the product is safe, that it has been thoroughly tested, and is free of toxic chemicals. The act empowering America’s Consumer product regulatory agency is called the Federal Hazardous Substances Act. As of 2011, the term “non-toxic” does not appear in the Federal Hazardous Substances Act (FHSA), rendering the term unregulated due to a lack of a definitive legal definition. The assumption that products are safe, when they bear the label of “non-toxic”, is based on a clever marketing illusion rather than fact. “Most parents and caregivers do not have access to lab testing. Even when purchasing toys that are not counterfeit, toxins are a particular challenge for consumers, especially because toxins cannot be identified by looking at the toy or the packaging” (Rhodes, 2021). The true chemical composition of children's toys is frequently unknown to physicians at the point of care. Due to the fact that nearly all toys currently sold in the United States are manufactured in China and have complex supply chains, there is no guarantee that the information provided by manufacturers, especially shadow factories, is accurate and consistent. Water bead injuries, insertions and swallowings should be reported to the Consumer Product Safety Commission (CPSC) and Poison Control Centers. Do not hesitate to seek medical guidance from specialists associated with the Pediatric Environmental Health Specialty Units.

For the above mentioned reasons, we propose recalling all brands of SAP beads from markets. In the meantime, That Water Bead Lady agrees with Alharbi & Dabbour, every incidence of complications following the ingestion of SAP beads should be reported.

## Reference

Acrylamide (EHC 49, 1985) ISBN 92 4 154189 X. Inchem.org. (1985). Retrieved 22 May 2022, from <https://inchem.org/documents/ehc/ehc/ehc49.htm>.

Agency for Toxic Substances and Disease Registry . (2012, December). Public health statement acrylamide - agency for toxic ... PUBLIC HEALTH STATEMENT Acrylamide CAS # 79-06-1. Retrieved February 22, 2022, from <https://www.atsdr.cdc.gov/ToxProfiles/tp203-c1-b.pdf>

Alharbi, N., Dabbour, M. Aspiration of superabsorbent polymer beads resulting in focal lung damage: a case report. *BMC Pediatr* 20, 262 (2020).  
<https://doi.org/10.1186/s12887-020-02168-9>.

Anand S, Aleem A. Duplication Cyst. [Updated 2022 May 4]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2022 Jan-. Available from:  
<https://www.ncbi.nlm.nih.gov/books/NBK564347/?report=classic>

C. Mullens, K. Coleman, D. Parrish, R. Vaughan. (2021) Orbeez ingestion can mimic duplication cysts as a cause of pediatric small bowel obstruction. *Journal of Pediatric Surgery Case Reports*, Volume 64, <https://doi.org/10.1016/j.epsc.2020.101711>

Caré, W., Dufayet, L., Paret, N., Manel, J., Laborde-Casterot, H., Blanc-Brisset, I., Langrand, J., & Vodovar, D. (2022). Bowel obstruction following ingestion of superabsorbent polymers beads: literature review. *Clinical toxicology (Philadelphia, Pa.)*, 60(2), 159–167.  
<https://doi.org/10.1080/15563650.2021.1987452>

Center for Science in the Public Interest. (2003) FDA urged to limit acrylamide in food CSPI says companies should reduce levels of known carcinogen. Retrieved from  
<https://www.cspinet.org/new/200306041.html>

Chalker-Scott. L., PhD, (2007). Super-absorbent water crystals miracle, myth...or marketing, MasterGardener WSU, Puyallup Research and Extension Center, Washington State University. Retrieved from <https://s3.wp.wsu.edu/uploads/sites/403/2015/03/hydrogels-3.pdf>

Chen, B., & Chrumbach, A. (1979). Estimation of polymerization efficiency in the formation of polyacrylamide gel, using continuous optical scanning during polymerization. *Journal of biochemical and biophysical methods*, 1(2), 105–116.  
[https://doi.org/10.1016/0165-022x\(79\)90017-4](https://doi.org/10.1016/0165-022x(79)90017-4)

Di Serafino, M., Mercogliano, C., & Vallone, G. (2015). Ultrasound evaluation of the enteric duplication cyst: the gut signature. *Journal of ultrasound*, 19(2), 131–133.  
<https://doi.org/10.1007/s40477-015-0188-8>

Environmental health & safety: Acrylamide. (n.d.). Einstein College of Medicine. Retrieved February 22, 2022, from <https://einsteinmed.edu/administration/environmental-health-safety/industrial-hygiene/acrylamide.aspx>

Faytrouni , F., Mujawar, Q., Sadiq, K., & Avinashi, V. (2021). Gel beads Ingestion: A Case Report with Management and Review of Medical Literature . Acta Scientific Clinical Case Reports 2.5, 2(5). Retrieved February 2022, from <https://actascientific.com/ASCR/pdf/ASCR-02-0122.pdf>.

Goel, A., Bell, D. (2013) Cytotoxic cerebral edema. Reference article, Radiopaedia.org. (accessed on 19 Feb 2022) <https://doi.org/10.53347/rID-24453>

Green-McKenzie, J., Khan, A., Redlich, C. A., Rivera, A., & McKinney, Z. J. (2022). The Future of Occupational and Environmental Medicine. Journal of occupational and environmental medicine, 10.1097/JOM.0000000000002676. Advance online publication. <https://doi.org/10.1097/JOM.0000000000002676>

Han, S. H., Chen, Y. C., Xian, Z. X., & Teng, Y. S. (2021). Superabsorbent polymer balls as foreign bodies in the nasal cavities of children: our clinical experience. BMC pediatrics, 21(1), 273. <https://doi.org/10.1186/s12887-021-02740-x>

Ige, A. O., Ayoola, O. I., Oladejo, E. O., Adele, B. O., Ola, O. O., & Adewoye, E. O. (2021). Gastrointestinal motility and intestinal structure following oral exposure to acrylamide in wistar rats. Research Journal of Health Sciences, 10(1), 27–39. <https://doi.org/10.4314/rejhs.v10i1.4>

Ige, Abayomi & Onwuka, Osah & Emediong, Idara & Tony, Odetola & Adele, Bernard O. & Adewoye, E. (2019). Oral administration of acrylamide compromises gastric mucosal integrity in Wistar rats. Journal of African Association of Physiological Sciences. 7(1):7-16, retrieved from <https://www.researchgate.net/publication/335425648> Oral administration of acrylamide compromises gastric mucosal integrity in Wistar rats

IvyPanda. (2020, February 26). *Potential Reduction in Irrigation Water Through the Use of Water-Absorbent Polymers in Agriculture in UAE*. <https://ivypanda.com/essays/potential-reduction-in-irrigation-water-through-the-use-of-water-absorbent-polymers-in-agriculture-in-uae/>

Kim, H. B., Kim, Y. B., Ko, Y., Choi, Y. J., Lee, J., & Kim, J. H. (2020). A case of ingested water beads diagnosed with point-of-care ultrasound. Clinical and experimental emergency medicine, 7(4), 330–333. <https://doi.org/10.15441/ceem.20.041>

Laulicht, B., Tripathi, A., Schlageter, V., Kucera, P., & Mathiowitz, E. (2010). Understanding gastric forces calculated from high-resolution pill tracking. *Proceedings of the National Academy*

*of Sciences of the United States of America*, 107(18), 8201–8206.  
<https://doi.org/10.1073/pnas.1002292107>

Mirza, B., & Sheikh, A. (2012). Mortality in a case of crystal gel ball ingestion: an alert for parents. *APSP journal of case reports*, 3(1), 6. Retrieved from: November 5, 2022  
<https://pubmed.ncbi.nlm.nih.gov/22953300/>

Murray , L. (1996, July). *Acrylamide*. Acrylamide (PIM 652). Retrieved June 26, 2022, from  
<https://inchem.org/documents/pims/chemical/pim652.htm#PartTitle:1.%20>

Murray , L. (1996, July). *Acrylamide*. Acrylamide (PIM 652). Retrieved June 26, 2022, from  
<https://inchem.org/documents/pims/chemical/pim652.htm#SectionTitle:2.3%20%20Diagnosis>

National Center for Biotechnology Information (2022). PubChem Compound Summary for CID 6579, Acrylamide. Retrieved May 22, 2022 from  
<https://pubchem.ncbi.nlm.nih.gov/compound/Acrylamide>.

National Institutes of Health. (n.d.). Acrylamide - health effects. U.S. National Library of Medicine. Retrieved February, 2022, from  
<https://webwisser.nlm.nih.gov/substance?substanceId=443&identifier=Acrylamide&identifierType=name&menuItemId=62&catId=83>

Poulsen, P. B. (Ed.). (2019). Survey and investigation of migration of monomers in toy materials Survey. *Survey of Chemical Sub-Stances in Consumer Products No. 175*. Retrieved November 2022, from  
[https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwiNvY2ooJP7AhUhX\\_EDHZ11DEEQFnoECAYQAQ&url=https%3A%2F%2Fwww2.mst.dk%2FUdgiv%2Fpublications%2F2019%2F02%2F978-87-7038-036-2.pdf&usg=AOvVaw3\\_zKJkWiF5AkFsQ7yD5Uxo](https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwiNvY2ooJP7AhUhX_EDHZ11DEEQFnoECAYQAQ&url=https%3A%2F%2Fwww2.mst.dk%2FUdgiv%2Fpublications%2F2019%2F02%2F978-87-7038-036-2.pdf&usg=AOvVaw3_zKJkWiF5AkFsQ7yD5Uxo).

Rhodes, H. (2021, November). trouble in toyland - uspirg.org. Trouble in ToyLand . Retrieved February 6, 2022, from  
[https://uspirg.org/sites/pirg/files/reports/Trouble-In-Toyland\\_2021/PIRG\\_Trouble-In-Toyland\\_2021.pdf](https://uspirg.org/sites/pirg/files/reports/Trouble-In-Toyland_2021/PIRG_Trouble-In-Toyland_2021.pdf)

Sangüesa Nebot, C., Llorens Salvador, R., Carazo Palacios, E., Picó Aliaga, S., & Ibañez Pradas, V. (2018). Enteric duplication cysts in children: varied presentations, varied imaging findings. *Insights into imaging*, 9(6), 1097–1106. <https://doi.org/10.1007/s13244-018-0660-z>

Shangareeva R.K., Valeeva G.R., Chendulaeva I.G., Mirasov A.A., Zaynullin R.R., Soldatov P.Yu (2019). Consequences of Hydrogel Granules Swallowing by Children: Case Study. *Current Pediatrics*. 2019;18(5):374-379. (In Russia.) <https://doi.org/10.15690/vsp.v18i5Alharbi.2062>  
retrieved from: <https://vsp.spr-journal.ru/jour/article/view/2236/898>



Sterling, M., Murnick, J., & Mudd, P. (2016). Destructive Otologic Foreign Body: Dangers of the Expanding Bead. *JAMA otolaryngology-- head & neck surgery*, 142(9), 919–920.  
<https://doi.org/10.1001/jamaoto.2016.1870>

Talukder R, Fassihi R. (2004) Gastroretentive Delivery Systems: A Mini Review, *Drug Development and Industrial Pharmacy*, 30:10, 1019-1028, DOI: [10.1081/DDC-200040239](https://doi.org/10.1081/DDC-200040239)

World Health Organization International Programme on Chemical Safety . (n.d.). Acrylamide. Acrylamide (PIM 652). Retrieved February, 2022, from <https://incchem.org/documents/pims/chemical/pim652.htm#SectionTitle:2.2%20%20Summary%20of%20clinical%20effects>

Zimmermann, L. Scheringer, M . Geueke, B. Boucher, J.M. Parkinson, L. V, Ksenia J. Muncke, G&M. Implementing the EU Chemicals Strategy for Sustainability: The case of Food Contact Chemicals of Concern, *Journal of Hazardous Materials*, (2022)  
[doi:https://doi.org/10.1016/j.jhazmat.2022.129167](https://doi.org/10.1016/j.jhazmat.2022.129167)