

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

Play is an integral part of childhood, and toys serve as the tools and materials for this occupation. Alice Hamilton, in her book "Exploring The Dangerous Trades," stated "...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". Physicians and researchers should view children as a unique class of workers to better prevent, identify, and protect them from potential toy-related hazards. Although children are not simply small versions of adults and have unique vulnerabilities that require specific attention, it is crucial to consider the occupational medicine perspective, literature, and expertise when evaluating toy-related risks and examining the actual harm linked to play, which is the pediatric occupation.

When it comes to assessing the dangers associated with toys and the potential harm they can cause during playtime, it's essential to acknowledge that children have unique needs and vulnerabilities, but it is equally important to utilize the knowledge and expertise of occupational medicine professionals, along with relevant literature and research, to ensure that our analysis is comprehensive and accurate. After all, play is a crucial aspect of children's lives, and it's our responsibility to ensure that they can engage in it safely and without unnecessary risk. Unfortunately, most medical students, residents, and practicing physicians have limited knowledge of Occupational Environmental Medicine (OEM), which is concerning. As noted by Green-McKenzie et al. (2022), many physicians are unaware of OEM until after years of practice in another field. The dangers of water beads illustrate the importance of robust OEM education for physicians and researchers because missed connections can occur when physicians lack OEM education, putting children's health and safety at risk.

Water beads, also known as crystal soils, water marbles, orbeez, fairy orbs, and super absorbent polymer balls, have various names. They are often imported and sold as agricultural soil conditioners, decorative products, and toys for children, without disclosing their chemical ingredients and composition. "Water beads are designed to absorb water, expand in size and volume, and are primarily made of polyacrylamide-polyacrylate copolymers" (Han et al., 2021; Redkar et al., 2021). Polyacrylamide has a longer life span and is cheaper than safer alternatives such as potassium polyacrylate and sodium polyacrylate (IvyPanda, 2020). Commercial toy manufacturers receive safety data sheets from suppliers, which may contain relevant information on chemical hazards, however, it cannot be assumed that toy manufacturers know the exact chemical content of all the components of their products. In the absence of strict specifications regarding chemical content, there may also be batch-to-batch variation in chemical mixtures used for toys. Furthermore, the chemicals used in toys may change rapidly in response to market forces (Toys and Chemical Safety: A Thought Starter, 2006; Glynn, 2012).

Polyacrylamide is generally considered non-toxic; however, it is made from the polymerization of neurotoxic acrylamide. Polymerization reactions are rarely complete, and therefore, residual monomers can still be present in plastics (Zimmermann et al., 2022). The amount of residual monomers depends on the polymer type, the polymerization process, and the technique used to reduce their content. In some cases, monomers can account for up to 4% by weight in the final material (Zimmermann et al., 2022). Polyacrylamide solid gels, including water beads, can contain high concentrations of residual and extremely toxic acrylamide monomers, ranging from 10% to 30% (Chen, 1979). According to the Albert Einstein College of Medicine, polymerized acrylamide gels should be handled with the same caution as acrylamide monomers to avoid repeated accidental exposure to neurotoxic acrylamide (Environmental Health & Safety: Acrylamide, n.d.).

Water beads can pass CPSIA standards for heavy metal and phthalate testing, but they can still pose a chemical risk. While polyacrylamide with regulated limits on residual acrylamide monomer content and specific uses is considered non-toxic and designated as such on SDS sheets, there are no regulatory specifications or standards for polyacrylamide used in toys or decor products. Overseas manufacturers of water beads are not required by the United States to disclose the initial amounts of monomer used or the assumed residual amounts and contamination,

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and testing for these levels is not mandatory. Even in the European Union, maximum concentrations of residual monomer content were not derived from toxicological risk assessments for infants or children (Zimmermann et al., 2022). The potential harm posed by water beads cannot be overlooked. Even though it may not be practical for manufacturers to test each water bead for monomer concentration levels, the absence of regulatory production conditions, monomer-limiting rules, and interference-free testing means that we cannot be certain if all the beads in a water bead package are safe. This level of uncertainty is unacceptable when it comes to protecting the health and well-being of children.

Water beads can pose a mechanical and chemical threat to children's health due to various factors, such as the increased degradation of water bead material back to its dimer monomer and the “unpredictable behavior of polyacrylamide in different environmental conditions”, temperature, UV light exposure, polymerization process, residual monomer content, inclusion content, and internal environmental conditions of the body (Chalker-Scott, 2007). Acrylamide monomers can easily enter an organism's circulatory system through dermal exposure, inhalation, and ingestion (Murray, 1996). The residual acrylamide levels permitted in polyacrylamide for agricultural purposes are thousands of times greater than those used in cosmetic formulations and water treatment for drinking water. For example, 500 ppm for agricultural purposes, 0.1 to 0.5 ppm for cosmetics, and less than 0.5 ppb for residual acrylamide limit for water suppliers by the EPA (Chalker-Scott, 2007; Center for Science in the Public Interest, 2003).

Although acrylamide loses some of its toxicity after polymerization, it can still corrode the nasal mucosa and be absorbed into the respiratory and digestive tracts, entering the systemic circulation and causing toxic reactions (Han et al., 2021). Oral exposure to acrylamide can also impair gastric emptying, intestinal motility, mucus secretion, and the digestive and absorptive functions of the small intestines, particularly the duodenum, leading to acrylamide-induced impaired neuronal signaling, autonomic neuropathy, oxidative stress, inflammation, and cell necrosis (Ige et al., 2021). Furthermore, acrylamide exposure can reduce gastric protective factors and lead to the dose-dependent degeneration of gastric mucosal integrity, making the patient's mucosa susceptible to erosions and lesions (Ige et al., 2019). Acrylamide can affect gastric and mucosal homeostasis, compromising its integrity, putting the patient's mucosa at risk for erosions and lesions (Ige et al., 2019). Therefore, it is crucial to keep in mind that both low and high doses of acrylamide can impact gastric and mucosal homeostasis.

The chemical composition of toys is usually unknown to physicians and consumers. When ingestion, insertion, or inhalation of water beads is suspected, extreme caution is necessary due to the significant threat they pose, both mechanically and chemically. Water beads do not behave like traditional foreign bodies because of their size, swelling capabilities, and chemical composition. Consumption and aspiration of water beads pose a significant public health risk, and the public should be informed of the dangers (Faytrouni et al., 2021). Alimentary tract duplications, also known as duplicate cysts, are congenital lesions of the gastrointestinal tract (Anand & Aleem, 2022). Research in gastrointestinal, pharmaceutical, and medical device fields has revealed that the most common strategies for achieving gastric retention are density mismatching, geometry-based, and bio/mucoadhesive doses (Laulicht et al., 2010; Talukder & Fassihi, 2004). Due to their inherent swelling behavior, ability to collect together and modify geometric shape, density mismatching, and mucoadhesive yet corrosive chemical nature, water beads can operate as duplicate cyst-type lesions along the gastrointestinal tract and achieve gastric retention.

Toys containing water beads or SAP-containing gel balls have been banned in several countries, including Poland, Italy, Malaysia, Turkey, and the United Kingdom (Redkar et al., 2021). Water beads have been banned in Thailand since 1984 due to their safety hazards. 2 deaths have been recorded in the medical literature, through voluntary submission, one in Pakistan 2012 and one in France 2019. Since 2015, the Australian Competition and Consumer Commission has urged businesses supplying water bead products as toys to cease immediately (Australian Competition and Consumer Commission, 2015).

Latest Research Information

- Prompt medical attention and evaluation are necessary for ingestion of water beads, but diagnosis can be challenging due to imaging difficulties (Faytrouni et al., 2021; Caré et al., 2021).
- Attempt prompt endoscopic removal for all patients with no signs of obstruction when gel beads may be in the upper GI tract (Faytrouni et al., 2021).
- Case management should aim for early removal of water beads, to prevent complications such as obstruction, lung injuries, exposure to toxic chemicals, nasal cavity injuries, hearing loss, seizures, brain injury, infection, sepsis, and death (Caré et al., 2021; Faytrouni et al., 2021; Han et al., 2021; Mirza & Sheikh, 2012; Gardner et al., 2021).
- Water beads can remain undetected in the respiratory tract, causing lung bronchiectasis, and may require flexible bronchoscopy for removal (Alharbi & Dabbour, 2020).
- Early recognition of otologic foreign bodies, especially expansile water beads, is crucial, as they can cause severe damage to middle ear structures and may require surgical intervention (Zalzal et al., 2022).
- A high degree of suspicion is necessary for the prompt diagnosis of water bead ingestion, as they can mimic duplicated cysts or present as traditional foreign bodies, leading to imaging difficulties (Mullens et al., 2021).
- Duplicate cysts are congenital abnormalities in GI tract alignment that can be diagnosed using ultrasound and can have cystic or tubular structures (Sangüesa Nebot et al., 2018; Di Serafino et al., 2015).
- Ultrasound is recommended for assessing potential water bead ingestion as it can mimic duplicate cysts, but it may underestimate the number of beads compared to endoscopic evaluation (Kim et al., 2020).
- Water beads can form bezoars in the GI tract without traditional symptoms, and complete removal through surgical management is required when causing intestinal obstruction (Faytrouni et al., 2021; Alharbi & Dabbour, 2020).
- Surgeons should be aware that water beads can collect lower in the GI tract and form a new mass if not completely removed, and ultrasound may miss beads lower in the digestive tract (Shangareeva et al., 2019).
- Pediatric patients who are young or non-verbal may not effectively communicate pain, and events may not be witnessed, making it challenging to diagnose water bead ingestion (Sterling et al., 2016).
- Age restrictions and parental observation may not be effective in preventing water bead ingestion, as nearly half of the reported incidents occurred in school-aged children, with 30% occurring while 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, fussiness, and irritability.
- Clinicians should closely monitor for signs of edematous and swollen bowel mucosa when performing enterotomy, as water beads can cause obstruction, form thick sludge, and result in severe complications such as infection, septicemia, and death. Acrylamide monomer poisoning can also have similar clinical manifestations to severe sepsis with acute nervous, cardiac, pulmonary, renal, and hepatic effects (Mirza & Sheikh, 2012; Caré et al., 2021; Banagozar Mohammadi et al., 2015; Mehrhof et al., 2008).

Cases of dermatitis or peeling rash on the mouth and/or hands should be handled with caution as they may indicate exposure to a higher level of monomer exposure. Clinicians should not dismiss the possibility of neurological damage in such cases, even if the patient did not lose consciousness. Diagnosis of acrylamide intoxication relies more on specific clinical features rather than electrophysiological and biochemical laboratory tests. Patients should be closely monitored for any signs of regression or neurological involvement, and referral to specialists such as developmental pediatricians, neurologists, and ECI may be necessary. In neurotoxicology, a patient's clinical history plays a crucial role in diagnosis. Tests to identify acrylamide blood or urine levels are not widely available, and laboratory studies are unhelpful. Evidence of peripheral neuropathy on nerve conduction studies can support the diagnosis of acrylamide neurotoxicity, but normal studies do not necessarily exclude the diagnosis. Accurately measuring acrylamide content in water beads, solid polyacrylamide is challenging due to interference concerns.

Therefore, data on the residual monomer content of polyacrylamide toys is scarce, and precise measurement during analysis is unlikely. In summary, cases of dermatitis rash on the mouth and/or hands should be handled with caution, and clinicians should be aware of the possibility of neurological damage. Diagnosis of acrylamide intoxication relies on clinical features, and patients should be monitored closely for any signs of regression or neurological involvement. Accurate measurement of acrylamide content is difficult, and specialist referral may be necessary for diagnosis and management. (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 time frame 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 cerebral 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 cerebral edema (Goel & Bell, 2013))
- Toxic Brain Encephalopathy

Water beads should not be marketed to children and their families as toys, sensory toys, or therapeutic aids. Water beads are not toys! "Non-toxic" and "food grade" are not regulated terms. Claims of "non-toxic" and "food grade" on a product's label or online listing should not be relied upon as the sole means of eliminating the risk of poisoning or chemical exposure during diagnosis or differential diagnoses. "Non-toxic" has a specific connotation that, for most people, means safe, pure, and not hazardous. Merriam-Webster defines the term "non-toxic" straightforwardly as "not toxic." Many consumers believe that when a product is labeled "non-toxic," it means the product is not only safe but has also been thoroughly tested and is free of toxic chemicals. As of 2011, the terms "non-toxic" and "food grade" do not appear in the Federal Hazardous Substances Act (FHSA), making them unregulated due to a lack of a definitive legal definition for consumer product labeling.

Unfortunately, the assumption that products are safer when labeled "non-toxic" is based on clever marketing rather than fact. As Rhodes notes, "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. Because nearly all toys sold in the United States are manufactured in China and have complex supply chains, there is no guarantee that the information provided by manufacturers, particularly when shadow factories are involved, is accurate or consistent. If a child is injured by water beads, it should be reported to the Consumer Product Safety Commission (CPSC) and Poison Control Centers. Don't hesitate to seek medical guidance from specialists associated with the Pediatric Environmental Health Specialty Units.

We strongly recommend recalling water beads marketed as children's toys due to their potential to cause indigestion, aspiration, and dermal contact hazards. Safe edible alternatives are available that don't pose the same risks. To

inform consumers of the dangers of water beads, it's crucial to prominently display clear, concise, and effective warning labels. Educational campaigns using clear language and messaging are essential to raise awareness of the risks associated with water beads. These campaigns should emphasize that water beads are not toys and should be kept away from children of all ages. The term "non toxic" should only be used in educational materials to inform the public about the lack of regulation around these products. Even under adult supervision, ingestion, insertion, and aspiration of water beads can occur due to the small size of the beads in their dehydrated form, their ability to remain undetected for long periods, their ability to bounce and roll under furniture and appliances, and the silent & rapid nature of injury incidents. Therefore, campaigns and public statements must stress the importance of avoiding water beads altogether and using safe alternatives.

Reporting any adverse incidents involving water beads to the CPSC and Poison Control is crucial. It's worth noting that while the National Poison Database System (NPDS) and the National Electronic Injury Surveillance System (NEISS) serve as critical resources for tracking incidents involving water beads, their data collection and analysis have limitations. The NPDS relies on voluntary reporting, which means the registry lacks accurate denominator data. The NEISS, on the other hand, lacks consistent data governance to predict injury incidences on a national scale. These factors highlight the crucial role that your reports play in ensuring appropriate data collection and analysis. By sharing your experience and concerns, you contribute to our understanding of the risks associated with water beads and help us identify patterns and trends that can inform policy and regulatory decisions. Your reports matter!

Remember, water beads can be toxic, and we must remain vigilant in our efforts to keep children safe. Together, we can make a difference and create a safer environment for our children. Thank you for your attention to this important issue.

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