Scientific Report

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Acknowledgments

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SCIENTIFIC QUESTION

How can superabsorbent polymers be applied to help natural disasters?

INTRODUCTION

Weather-related natural disasters cause tremendous amounts of damage, and the cost of these phenomena has slowly been increasing. Last year, 2.78 billion dollars was spent in Canada, to deal with residential damage from floods alone[15]. Nowadays, weather disasters cost over CAD 152.68 million, which is a large increase compared to the early 1970s, when it was roughly CAD 11.10 million[15]. Superabsorbent polymers can absorb and retain large amounts of water. Using these polymers, we hope to provide a cost-effective, biodegradable solution to dealing with floods. This is why we've posed the question: what are superabsorbent polymers, and how can they be used to improve our environment?

BACKGROUND INFORMATION

Superabsorbent polymers- SAPs, for short, are a type of polymer that can absorb many times more of its weight in water. Polymers themselves are synthetic or natural compounds, made up of macromolecules. Cellulose, for example, are natural polymers that make up the building blocks of living organisms.

The properties of polymers are based on their molecular structures. For example, linear structured polymers are often strong and thermostable materials. Their structure is made up of repeating monomers, resembling a string of pearls. The simple structure is easy to stack, giving the polymer a high density, as well as boiling and melting points.

Cross-linked polymers are shaped like a net, are often rigid, and have a high melting point. superabsorbent polymers have a cross-linked structure. They contain hydrogen bonds, which contribute to their stable properties.

Superabsorbent polymers contain polyacrylate compounds, which allow them to soak up and retain large amounts of water. There are many different types of superabsorbent polymers, including sodium polyacrylates, potassium polyacrylates, and grafted superabsorbent polymers. The most common type of superabsorbent polymers are sodium polyacrylate polymers. They contain sodium ions which help to facilitate the movement of water into the polymer network.

Superabsorbent polymers absorb water through osmosis. Sodium polyacrylate, the most common type, contains a large amount of sodium ions. When it comes in contact with water, it turns into a gel-like substance. Water moves into the polymer network, and sodium moves out of it, to equalize the amount of water and sodium amounts both inside and outside the structure. The cross-linked structure of superabsorbent polymers helps with the absorption. Crosslinkers hold the structure together as water moves into the polymer network so that the polymer does not dissolve or break apart inside the water.

HYPOTHESIS

We hypothesize that the use of superabsorbent polymers can be a cost-effective, environmentally friendly option to deal with water-related natural disasters like floods and droughts. This is because these polymers can absorb and retain large amounts of water - to help with floods, and can also slowly release water - to help with droughts.

CONTROLLED VARIABLES

Our controlled variables are the floods themselves. While we acknowledge that all floods are different in intensity, temperature, and other environmental factors, testing out how superabsorbent polymers work in comparison to other technologies can still be applied.

MANIPULATED VARIABLES

Using superabsorbent polymers (SAPs) instead of existing flood technologies like watergates and water-inflated property protectors (WIPP). Both of which are effective in stopping water, but not getting rid of it.

RESPONDING VARIABLES

The responding factors would be how much it costs to repair the damage caused by the floods, and the amount of environmental disturbance the repairs create. Additionally, the repair time and impacts of repairs on families should be taken into account.

APPLICATION

Currently, superabsorbent polymers are used in common items, like diapers, ice packs, and cable wrapping. However, we believe that superabsorbent polymers can be used on a greater scale, such as when dealing with droughts and floods. Sodium polyacrylate, a common type of superabsorbent polymer, absorbs water using osmosis. The sodium ions move out of the polymer, and water molecules move into it. Sodium polyacrylate compounds can be used to absorb massive amounts of water in floods, preventing excessive damage to residential, as well as other areas. Additionally, there are some superabsorbent polymers, such as polyacrylamide copolymers that are made to slowly release water, which can help with droughts. For example, these polymers can slowly release water in agricultural fields, to help keep plants alive while also preventing water wastage.

CONCLUSION

Superabsorbent polymers have proven to be extremely effective materials that can absorb large amounts of water. Throughout our research, we compared superabsorbent polymers to existing flood and drought technologies, for example, sandbags and drip irrigation, and have concluded that our current technologies are very costly, and do not solve the issue of liquid-related natural disasters. By using superabsorbent polymers, floods and droughts can be dealt with in a more timely, and cost-effective manner. Based on the research done, we can conclude that superabsorbent polymers will be effective tools when dealing with floods and droughts.

NEW QUESTIONS

From our research, we learned that superabsorbent polymers are thrown into landfills once they're used. We want to know, how can we reuse superabsorbent polymers, to limit the environmental impact? Additionally, we want to know how superabsorbent polymers can be manufactured in a safer way, to prevent the chance of human injury.

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5 Page Summary

Polymers are the base of any living organism or non-living substance. Specifically, superabsorbent polymers (SAP) are polymers that can absorb large amounts of water. These polymers are commonly found in diapers and other everyday household appliances. Over the years, SAPs have started to integrate into people's everyday lives. This project wishes to take the application of SAPs to the next step by applying them to natural disaster relief such as flood and drought prevention. Through our research, we focused on gaining a better understanding on the structure, function, uses, and applications of superabsorbent polymers. We also made comparisons between current flood and drought technologies in comparison to the function and structure of superabsorbent polymers. In this project, we will be researching further into the science behind superabsorbent polymers, how they are made, how they work, and some current natural disasters and how they compare to superabsorbent polymers.

Polymers can be split into two types of polymers; natural and synthetic. An example of natural polymers is cellulose and DNA, which are the building blocks of animals, plants, and other living organisms. Likewise, an example of synthetic polymers is nylon. Both types of polymers are made up of repeating units called monomers. The structure of polymers determines their physical properties. Of these molecular structures, four categories can categorize these polymers. These include linear polymers, branched polymers, cross-linked polymers, and network polymers. Linear polymers consist of a structure that resembles a single strand of pearls. They are easily aligned and are often strong, thermally stable materials. Similarly, branched polymers are made up of one strand but with chains sprouting out of the main strand. Network polymers are those of a 3D structure of interconnected chains. The chain-like structure creates durable and hard materials like adhesives. Cross-linked polymers have structures that are interconnected at various points similar to that of a net. This structure improves rigidity and melting resistance. An example of a polymer with a cross-linked structure is superabsorbent polymers.

Superabsorbent polymers are made from polyacrylate compounds, which allow these specific polymers to soak up and retain large amounts of water. Superabsorbent polymers can be differentiated into 5 specific types: sodium polyacrylate, potassium polyacrylate, and grafted superabsorbent polymer. The most common type of superabsorbent polymer is sodium acrylate, which is commonly used in personal hygiene products and diapers. These polymers contain sodium ions. Unlike sodium acrylate, potassium polyacrylate consists of potassium ions. These SAPs are specifically developed for plants because the potassium ions from potassium polyacrylate can be absorbed by plants. Grafted superabsorbent polymers are based on one of the two polymers previously mentioned, and then grafted with the other polymer to enhance the performance of the polymer. Specifically, starch-grafted copolymers are similar to grafted SAPs because they are based on two structures. Starch-grafted copolymers consist of natural starch and synthetic polymers which makes them biodegradable. A superabsorbent polymer that may be useful for drought conditions is polyacrylamide copolymers. This type of polymer gradually releases water making them useful in agricultural settings. Additionally, cellulose-based polymers are made from cellulose which makes it one of the biodegradable superabsorbent polymers. This type of polymer is often used in medical settings.

As aforementioned, polymers are synthesized by creating long chains of monomers. Synthetic polymers are synthesized through processes called polymerization or polymer synthesis. This process is when monomers are chemically bonded to form long chains by using heat or light as a catalyst. Superabsorbent polymers are crosslinked linear hydrophilic polymers that create a 3-dimensional cross-linked structure. Crosslinkers bind the polyacrylate chains that make up the polymer together to create this 3D structure. Polymers with a looser structure, with more room for water result from few cross-links. Likewise, more cross-links create a denser, less absorbent material. Another factor that enhances the absorption of SAPs is the presence of sodium ions which facilitates water movement in the polymer structure. Similarly, carboxyl groups, -COOH, ionize when they come in contact with water and become negatively charged, which, in turn, attracts water molecules.

Next, we researched how superabsorbent polymers absorb water to gain a deeper understanding of the structure and how SAPs work. Sodium polyacrylates are the most common SAPs and they absorb water through osmosis. As these polymers come in contact with water, the water starts to move into the cross-linked network structure of the polymer which then causes sodium ions to leave the network allowing more space for water. Sodium polyacrylate can absorb up to almost 800 times its mass in distilled water, but only 300 times its mass in tap water. The reason behind the difference is that tap water contains sodium ions, so there is less sodium that may leave the structure to reach an equilibrium. Despite the discrepancy between distilled water and tap water absorbency, the polymer still manages to absorb a significant amount of water. As superabsorbent polymers absorb water, they turn into a gel-like substance because of the formation of hydrogen bonds. When the environment around the polymers dries, the polymer network starts to shrink forcing the water out of the net-like structure. Additionally, superabsorbent polymers contain hydrophilic molecules which attract water molecules encouraging them into the polymer network. Due to the addition of sodium ions for absorption levels for sodium polyacrylate SAPs, if fewer sodium ions are available in the water, then the rate of diffusion will be greater to reach equilibrium between the external and internal environment of the polymer.

There are many different methods for the absorption of liquids in superabsorbent polymers. One of the most common methods is ion attraction which can be found in sodium polyacrylate SAPs. Superabsorbent polymers mainly absorb water through osmosis. Due to their porous structure, it makes it easier for liquids to pass through and be absorbed. Hydrophilicity is another example of how SAPs absorb water. This is when hydrophilic groups in the SAPs' structure form hydrogen bonds and other interactions with water molecules. The addition of hydrophilic groups helps enhance absorption between SAPs and water molecules. The osmotic pressure effect is another factor that influences the absorption of liquids. A change in osmotic pressure between the external and internal environment of SAPs. The higher the water concentration inside the polymer network, the more pressure continues to attract water molecules into the polymer which increases the absorption rate.

Superabsorbent polymers are a new technology that is rapidly gaining recognition through applications in everyday life. In this project, we researched various real-world applications of SAPs in hopes of gaining a better understanding of the purpose and advantages of these polymers. One of the most widely known uses of superabsorbent polymers is in diapers. Diapers contain sodium polyacrylate, which is not biodegradable but extremely absorbent and is the most common type of SAP. Other uses include personal hygiene products, biohazard absorption and protection, wound care dressing, meat and fruit pads, and retaining liquid waste. All of these products are meant for absorbing and retaining fluids. Contrary to these products, ice packs also contain the sodium polyacrylate superabsorbent polymer. Many manufacturers use SAPs in ice packs because they can absorb large amounts of water and are good for cooling solutions. Another unique application of superabsorbent polymers is the fake snow used in movies. Since superabsorbent polymers turn into a gel form after absorbing water, they give off the impression of snow. Out of all of the applications we looked into in this project, two uses of SAPs caught our attention. This is the usage of flood control products and using SAPs to reduce drought stress. Since SAPs are widely known for their ability to absorb and retain large amounts of water, they can be used in sandbags. This allows SAPs to absorb and lock in flood water for efficient transportation, which is more effective than the regular sandbag. In terms of droughts, specific types of superabsorbent polymers can retain water and release it when needed. In certain conditions, water absorbed by SAPs can be released slowly, which is also useful in gardens and agriculture.

Although superabsorbent polymers may have many uses and are rapidly integrating into our daily lives, there are still many disadvantages to using SAPs and the growing popularity of these polymers. The main worries of SAPs are their environmental impacts on our ecosystem. The most common superabsorbent polymers, sodium polyacrylate, cannot biodegrade which will cause it to accumulate in the environment. In some cases, polymers can be reused and recycled but in most cases, they will be disposed of in a landfill. Over time the polymers will accumulate which will prevent water from reaching plant roots and soil. Aside from preventing water, many sources have proven that these polymers may also release carcinogens such as acrylamide and formaldehyde. Manufacturing SAPs also releases many dangerous chemicals which, without proper protective equipment, will detrimentally impact the workers' health. Another disadvantage of dealing with SAPs is that some individuals may have allergic reactions or skin irritation when in direct contact with particular materials used in SAPs. Polymers are also choking hazards and may cause digestive problems when ingested which makes them not very child-friendly.

Even with the many disadvantages of SAPs, the advantages outweigh many of these disadvantages which is the reason why manufacturers still choose to use SAPs in their products. One of the main characteristics and advantages of SAPs is that it is extremely absorbent and can retain water for a long time. In addition to retaining water, these polymers cannot be wrung out in comparison to a sponge where the liquid can easily be drained. SAPs are often used to prevent leakage of toxic liquids into the environment. Since SAPs turn into a gel that cannot be wrung out, it is a clean and effective way to prevent liquids such as food packaging liquids from impacting the quality of the product. The liquid that the polymers absorb can also be safely disposed of into the environment without worries of it spilling harmful substances. These polymers are fairly accessible and cost-effective. One package of 500 grams of superabsorbent polymers is on average $30 for a box on Amazon. Many sites and companies manufacture superabsorbent polymers and can be purchased online or on-site. Overall, superabsorbent polymers have many disadvantages but they also have many advantages that can outweigh the negative impacts they may have.

In addition to researching superabsorbent polymers, research on current flood and drought technologies was also done for a comparison with the function of polymers. Some flood technologies include watergates, water-inflated property protectors (WIPP), flood barrier socks, modular flood prevention solutions, heritage flood guard systems, storm sewage drains, sandbags, pumps, and sponge cities. Most of these technologies only act as barriers to floods without actually removing the flood water from the area. Some examples of flood barriers include the common sandbag which is simple but effective. Other technologies may remove flood water but these technologies require a lot of resources and energy that third-world countries may not have access to. We believe that SAPs will not only act as a barrier for floods but also absorb and retain the flood water to be disposed of where needed. Additionally, many different drought technologies are currently in use. For example, rainwater harvesting collects water from the rain and stores it until it is needed during a drought. This method is only beneficial for areas with rain and not very effective for areas where it is dry and rainless throughout the year. Wastewater recycling is another method for drought mitigation which includes a complex system that rids wastewater of toxins and other contaminants producing fresh water that is ready for use. This system requires many resources and money that many countries do not have access to. Much like wastewater recycling and rainwater harvesting, other technologies also require lots of resources and specific prerequisites that some countries do not have access to.

Ultimately, we believe that using superabsorbent polymers to deal with natural disasters is an effective and efficient method that can be developed further in the future. Through our research, we have discovered that even though SAPs have many flaws and imperfections, the benefits of these polymers still outweigh these disadvantages. From learning more about the functionality of SAPs and the structure of these polymers we concluded that it will be highly effective for drought and flood resistance. As our research progressed, we discovered that most superabsorbent polymers are not biodegradable and are often thrown in landfills which will negatively impact our environment. Through this project, we wish to spread awareness of the environmental impacts of SAPs and hopefully find a way to effectively and efficiently dispose of these polymers without impacting the ecosystem. Eventually, we concluded that superabsorbent polymers should be used for flood and drought resistance due to their high level of absorption of liquids and other characteristics such as polyacrylamide copolymers which can gradually release water into the environment.