ST.GALLEN SYMPOSIUM

Global Essay Competition 2024

Title: Navigating a World with Dwindling Sand Resources Through Sustainable Technology and Smart Policies

Essay:

Introduction

The saying "the smallest grain of sand can create mountains of possibilities" serves as a powerful metaphor for the profound importance of sand. To the average person, sand might be just something that follows you home from vacation, but it is one of the most extracted materials globally, playing a critical role in constructing our society's physical "mountains" (Bisht, 2021). Beyond replenishing beaches, it is widely used in industry and development for concrete, glass, cement mixing, and fracking. While it seems unlikely to run out of something as common as sand, the reality is more nuanced. In addition to a rise in global demand in the last 30 years, water shortages have begun reducing the supply of sand from rivers, oceans, and lakes, leading to an increasing global scarcity (Peduzzi, 2014). This scarcity poses a looming threat to rapidly developing nations like India and China who rely on sand to build infrastructure (Ioannidou et al. 2020). This essay aims to dissect the contemporary challenge of sand scarcity and propose sustainable, technological, and policy-driven solutions to navigate an increasingly sand-scarce world.

Background

Sources of Sand

If the concept of sand scarcity seems counterintuitive, you would be correct in a literal sense. Sources of sand are diverse and widespread, from rivers, beaches, lakes, oceans, deserts, and even artificially produced from rocks and boulders. However, usable sand is highly limited by the shape of the sand grain and ease of extraction (Bisht, 2021). Sediments from rivers are often preferred for construction materials due to their grain sizes and proximity to urban spaces (Bisht, 2021). Deeper lakes and marine sediments can be used but are more costly, as they require machinery and technology to extract the sand or extra processing to remove salts from marine sand (Bisht, 2021). Desert sand, while plentiful, is shaped spherically, which is incompatible with concrete production (Bisht, 2021). Creating sand can be financially and energy-intensive (Bisht, 2021).

Uses of Sand

Sand is mined for three primary functions: industrial use, fracking, and land replenishment. Industrial usage can range from roadway and building construction to golf course maintenance and plaster (Peduzzi, 2014). In Oregon, USA, 42% of sand was used in concrete, 26% for roads, 13% for construction fill, 10% for concrete aggregate, and 6% for miscellaneous uses (U.S. Geological Survey, 2023). The remaining 3% was used for things like concrete products, filtration, golf course maintenance, and snow and ice control (U.S. Geological Survey, 2023). Sand is also a critical source of silicon dioxide, which is essential for creating glass (Glass for Europe, 2020). The utilization of sand in construction is extensive.

Limited to the USA, Hydraulic fracturing (fracking) is also a driver of sand extraction. This process requires large quantities (up to 10,000 tons of sand) to maintain fracking and ensure continuous gas flow (Biersted, 2015). In the largest fracking basin in the world, Permian Basin, they used up to 23 million tons of sand, with estimates to increase demand to 54 million tons (Black et al., 2018).

Finally, land replenishment, a key strategy to counter coastal erosion, has emerged as a response to the retreat of approximately 15% of the world's sandy beaches by a meter or more per year in the last decade (de Schipper et al., 2020). This process involves adding sediment onto or directly adjacent to an eroding land mass (like a beach) to build more area. The sediment is transported to the coast by barge, pipeline, or truck, then pumped, sprayed, or dumped onto the site (de Schipper et al., 2020). Bulldozers and machinery then sculpt the sand into planned shapes, steepening and widening the area (de Schipper et al., 2020). The transformed land may result in altered currents, waves, wind, sediment transport, and grain size that can have cascading environmental effects (de Schipper et al., 2020). Since its inception in 1921 at Coney Island, NY, beach nourishment has become a necessary cost for many locations around the United States, and the federal government subsidizes the cost up to 50-75% (Muka, 2015).

These three processes have a high demand for sand, with no indications of slowing down. While there are seemingly endless sources of sand, the world's consumption of sand and gravel is twice the yearly amount of sediment carried by all the world's rivers (Sand Extraction). Cement demand in China has increased exponentially by 430% due to rapid development in 20 years and 60% by use in the rest of the world (Sand Extraction). Long-term solutions aimed at sustainability, new technologies, and policy reforms are necessary to control scarcity and conservation.

Cost of Sand

Financial Trends

The price of sand used for development has increased dramatically in the last 15 years. Sand is measured in metric tons or mt. The cost has raised 51% in the US between 2012-2022 ($7.3/mt to $11/mt) and 36% globally between 2007-2022 ($7/mt -$9.5/mt) (Statistica, 2023, Maximize Market Research, 2024). Specialty sands, such as the frac sand used in fracking, have risen even more in times of scarcity (+166%), from $26.5/mt in 2022 to $70.5/mt (Maximize Market Research, 2024). Despite growing scarcity, the sand market is expected to grow 6.4% between 2024 and 2030, with several production investments from key players (Maximize Market Research, 2024). Increasing government regulations, like moving locations where sand can be retrieved to less populated areas, can further increase operation costs, such as higher transportation after extraction (U.S. Geological Survey, 2023).

Despite its impermanent solution, the use of land replenishment projects has increased over the years as well as cost. In many land replenishment projects (especially beaches), the sand can be washed away within 2-5 years, making them dependent for continued replenishment. Miami Beach's projects over the years have been infamously touted as an "obvious failure and praised as the cities savior" (Miami Beach, 2023). Locations like Orange County, CA, are spending $23 million/yr to replenish beaches (Boraks, 2022). Adjusted for inflation, federal, state, and local governments have spent more than $1 billion on North Carolina Beach (since the 1950s) and more than 600 million in South Carolina (Boraks, 2022).

Environmental Impact

Sand extraction can have immense environmental impacts. The retrieval of sand is destructive; offshore dredging or mining can kill organisms and change the shape of the bottom of the water body (de Schipper et al., 2020). Marine sand extraction can alter waves, currents, and sediment transport in the long term, resulting in even more erosion in the future (de Schipper et al., 2020). Land replenishment projects can threaten the local food webs if the new sand does not match the area. Larger grain sizes can obstruct feeding from birds and fish and disrupt organism reproduction; finer sand can suffocate animals who live in the sand and obscure prey in muddier waters (de Schipper et al., 2020).

Once extracted, the transportation of sand is energy and carbon intensive. Often, sand is transported long distances through freight transportation or by trucks, trains, airplanes, or ships. In China, sand and gravel transportation was approximately 17.8 billion tons, approximately 38% of the total freight transportation (Zhu et al., 2023).

Solutions to Impending Scarcity? Optimizing What We Have

Recycling Materials

The world could meet a rapidly growing demand for sand by increasing recycling and material efficiency (Zhong et al., 2022). Unlike other raw materials, sand can be recycled countless times; almost 90% of demolished buildings can be recycled without losing quality (EqualTimes). On average, the United Kingdom has 72 million tons of waste from construction, 95% of which could be reused (World Economic Forum, 2023). Several governments and private companies have set goals or standards to encourage recycling materials. Zurich, requires that all publicly owned buildings be made using recycled concrete (World Economic Forum, 2023). The company Cemex has set the goal of increasing the amount of waste captured as alternative fuels and raw materials by 50% by 2030, with 95% of waste being reused, recycled, or recovered (World Economic Forum, 2023).

Recycling or recirculating materials can also lead to using waste from other industries to develop new concrete mixes and cement blends (World Economic Forum, 2023). Demolition waste can be reused for entire structures, as gravel for road construction, aggregate concrete. Using more cement additives such as slags, fly ash, and pozzolans can increase the sustainability of materials (World Economic Forum, 2023). Parts of cement, like clinker, can be replaced with less carbon-intensive materials such as limestone calcined clay to reduce the total amount of material or substitutes needed (World Economic Forum, 2023).

Innovative Technology

New technology, such as 3D printing and AI, can help reduce the material used during construction. Holcim has invested in 3D construction printing technology to reduce material use by up to 50% (World Economic Forum, 2023). Similarly, Heidelberg Materials has invested in projects developing sensor technology and artificial intelligence (AI)-driven software to optimize processes for concrete (World Economic Forum, 2023). Giatec has developed multiple sensors that ultimately reduce material demand and improve the sustainability of construction activities (World Economic Forum, 2023). In collaboration with Metsä Wood, a Finnish producer of engineered wood products, Heidelberg Materials is also developing a hybrid element to combine concrete and wood for future building structures (World Economic Forum, 2023).

Innovation like this is also how partnerships between engineering companies and climate organizations can use technology to create less sand-intensive solutions for coastal erosion. Green infrastructure, such as coral and oyster reefs, salt marshes, mangroves, and seagrass meadows, can be used to counter coastal erosion. This can be done through vegetative planting projects or by using new technologies to build rigid structures for organisms to grow on. In Virginia, a 20-year-long reseeding project has resulted in 10,000 acres of seagrass, reducing coastal erosion, carbon burial, and fisheries habitat (McGlathery et al., 2012; Orth et al., 2020). In Thailand, Chulalongkorn University has developed 3D-printed concrete coral reef structures to help restore damaged reef habitats (Chula). These structures were successful, resulting in protection against tides on stormy days, habitats for sea creatures, and sources of food for humans (Chula). Technology and research can be utilized to protect coastal communities with infrastructure that can mitigate erosion more successfully than sand replenishment.

Policy Implementations

The industry's goals and governmental limits on sand usage and its environmental impacts have begun to shift. The EU's Circular Economy Action Plan focuses on construction and buildings as one of eight priority sectors (World Economic Forum, 2023). China's Circular Economy plan includes a target of 60% reuse for construction waste by 2025 (World Economic Forum, 2023). The Global Cement and Concrete Association has set guidelines for co-processing fuels and raw materials in cement manufacturing to limit carbon emissions (World Economic Forum, 2023). Despite the optimism and good faith that has begun to develop, there are steps governments and industry leaders can take to make sure progress and innovation continue to move forward.

Recommendations:

1. More regulation by government entities to curb irresponsible extraction and illegal activities.

2. Better data tracking for management recommendations and policies that reflect actual market trends

3. Tax incentives for companies to recycle industrial waste and reduce sand usage.

4. Tax burdens for environmental destruction and carbon emissions to encourage optimizing the extraction, transportation, and building process.

5. Fellowship programs and research funds to continue innovating efficient technology such as AI and developing alternatives to sand

6. Global communication between sand-rich and sand-poor locations to best move resources while minimizing carbon emissions. This is most relevant for rapidly developing

countries like China and India, which have a high demand for sand but may have limited access to nearby resources.

7. In cases where sand usage can't be limited, build infrastructure intended to last. This will limit the long-term need for more buildings or repairs.

8. Clear messaging to influence public perception of sand and pressure the industry to be sustainable and minimize emissions.

9. Continued collaboration between environmental and development organizations to produce green infrastructure that can replace or improve the lasting effects of land replenishment projects.

Conclusion

Outside of water, sand is one of the most widely used resources in the developing world. It is the backbone of most significant buildings, roadways, and oil fracking (in the US) and protects our coastlines. As construction and development continue to skyrocket while coastal erosion chips away at our coastal cities, it is critical the industries that depend on sand aim to optimize their current materials. While doing this, they can also look to recycling materials, optimize new technologies to broaden their material options, and lobby for regulation and policies to reduce impending scarcity. With increased collaboration and effective regulatory frameworks, the industrial sector can improve its environmental impact and decrease sand scarcity.

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