Reclaiming abandoned mine tailings ponds for agricultural use: Opportunities and challenges

Haoxuan Yu *, Izni Zahidi**, Chow Ming Fai***

Department of Civil Engineering, School of Engineering, Monash University Malaysia, Jalan Lagoon Selatan, 47500, Bandar Sunway, Selangor, Malaysia

1. Introduction

As the worldwide demand for natural resources escalates, mining activities are consequently expanding, resulting in a growing volume of mining waste which must be stored in tailings ponds (Yu, 2023). When tailings ponds reach their maximum capacity, they frequently become abandoned, occupying vast tracts of land. The problem of abandoned tailings ponds, however, goes beyond merely land occupation (Srirattana et al., 2021). These ponds often harbor various hazardous materials, including toxic chemicals, heavy metals, and other pollutants (Li et al., 2022). If not appropriately managed and treated, these contaminants can leach into nearby water sources and ecosystems, wreaking havoc on the environment and public health. Nevertheless, there is potential to repurpose abandoned tailings ponds as agricultural land (Stanislaw et al., 2007), which would not only mitigate the environmental impact of mining waste, but also transform unproductive land into fertile ground for food production (Liu et al., 2015). Numerous examples of successfully reclaimed tailings ponds being converted into agricultural land, have emerged in recent years. One such instance is a study published in 2021 (Zhang et al., 2021), which reported that the land surrounding the Liujiadian tailings pond in Beijing, China, underwent reclamation and was transformed into farmland.

However, the process of reclaiming tailings ponds for agricultural purposes also presents a myriad of practical obstacles and challenges, including addressing the issue of heavy metal elements and other contaminants present in the soil of the tailings ponds, which may pose serious risks to both the environment (Tang et al., 2020) as well as food security (Yu and Zahidi, 2023a). If these challenges could be effectively overcome, the benefits for humanity would be immense. Transforming abandoned tailings ponds into agricultural land would not only alleviate the environmental pollution issues associated with these ponds (Ouyang et al., 2020), but also present a practical solution to food scarcity. Through increasing the available arable land for farming, we could significantly contribute to global food security, helping to meet the needs of a growing population (Kopittke et al., 2019; de Paulo Farias and dos Santos Gomes, 2020). Furthermore, this conversion of land would encourage sustainable agricultural practices, furthering our efforts towards a greener and more environmentally responsible future (Pineiro et al., 2020; Ma and Wang, 2020).

The management of tailings ponds has recently emerged as a pressing issue. However, the notion of transforming these ponds and abandoned mining sites into agricultural land is still in its nascent stage, with only a few instances of success to date. Given the limited instances of actual execution, the feasibility of such transformation remains a subject of ongoing debate. Consequently, this paper, positioned as a discussion article, endeavors to comprehensively examine the opportunities and challenges that emerge in the process of converting abandoned tailings ponds into productive agricultural land. Additionally, it aims to propose

* Corresponding author.
** Corresponding author.
*** Corresponding author.
E-mail addresses: Haoxuan.Yu@monash.edu (H. Yu), Izni.Mohdzahidi@monash.edu (I. Zahidi), Chow.MingFai@monash.edu (C.M. Fai).
the viable solutions and strategies to tackle these challenges effectively, ultimately contributing to a more sustainable and environmentally responsible, approach to land reclamation and food production.

2. Opportunities and challenges

Without a doubt, the transformation of abandoned tailings ponds into agricultural land would represent a substantial boon to humanity. Several opportunities emerge from this endeavor (as shown in Fig. 1):

Opportunity 1: Primarily, the reclamation of degraded tailings pond land can significantly help address food security concerns, especially in regions where arable land is scarce (Gomiero, 2016), which is in line with Sustainable Development Goal 2 (sdgs.un.org). This process also paves the way for the advancement of sustainable agriculture, urging farmers to embrace environmentally-conscious practices like organic farming and eco-agriculture (Fiebrig et al., 2020).

Opportunity 2: Furthermore, the transformation of tailings pond land can generate new economic opportunities for local communities (Wang et al., 2016), which is in line with Sustainable Development Goal 8 (sdgs.un.org). Agriculture not only provides a source of income for farmers but also creates jobs in processing, distribution, and marketing sectors. Moreover, such endeavors can stimulate the growth of ecotourism (akin to mine parks) and related sectors, thereby injecting vitality into the local economy (Sengupta et al., 2018).

Opportunity 3: Moreover, the reclamation of tailings pond land for agricultural use can result in considerable environmental benefits (Pencea et al., 2023), which is in line with Sustainable Development Goals 3, 14 and 15 (sdgs.un.org). By rehabilitating the land and advocating for sustainable agriculture practices, various positive outcomes can be achieved. These include a reduction in soil erosion, improvement of water quality, and enhancement of the overall health and functionality of ecosystems. In turn, these benefits contribute to the long-term preservation of natural resources, fostering a more sustainable environment for future generations (Ukhurebor et al., 2022a; Wang et al., 2014).

Nonetheless, seizing these opportunities requires overcoming several challenges. The successful conversion of abandoned tailings ponds into productive agricultural land is not without its obstacles (as shown in Fig. 1):

Challenge 1: One significant challenge is presence of toxins and heavy metals in the soil adversely affecting both the environment and human health (Tang et al., 2022). Prior to farming on the land, soil treatment and remediation, may be required, which can be expensive and lengthy (Song et al., 2022). To determine potential environmental risks and project viability, it is essential to conduct a comprehensive site assessment, including soil and water sampling, as well as analyzing contaminants and their distribution (Zhang et al., 2020).

Challenge 2: The land in tailings ponds is often physically transformed, exhibiting considerable changes in topography, soil structure, and drainage patterns (Geng et al., 2022). For instance, the creation of a tailings pond may result in alterations to the land’s elevation and surface contour, as depicted in Fig. 1. Restoring these features can be difficult, and it may take years for the land to recover and become suitable for farming.

Challenge 3: Lastly, the cost of reclamation can pose a substantial financial burden for many mining companies (Sarkkinen et al., 2019). Consequently, taxpayers often bear the expense of environmental cleanup as governments step in to cover the costs. This highlights the need for a more efficient and economically viable approach to tailings pond land reclamation, balancing the benefits of land restoration with the financial constraints faced by various stakeholders.

As previously stated, transforming tailings ponds and mining lands into agricultural zones is currently largely theoretical and not fully practical. However, drawing from the few cases that have been executed, this discussion paper, as a pioneer in this field, proposes the following potential strategies to tackle the inherent challenges. These suggestions aim to make the reclamation of tailings ponds and mining lands more feasible and sustainable:

Regarding Challenge 1 and Challenge 2, a typical approach involves improving the treatment of tailings pond soils to gradually eliminate contaminants and restore the altered soil structure (Liu et al., 2020). However, an alternative approach we have had the pleasure of observing involves constructing containment measures to isolate the land beneath the tailings ponds (Yu and Zahidi, 2023b). By placing new soil on top and planting crops, the issue of land occupation caused by abandoned tailings ponds can be effectively resolved while avoiding the negative effects of contaminants and changes in land structure. This innovative method presents a practical and efficient solution for reclaiming tailings pond land for agricultural use.

Regarding Challenge 3, to tackle the financial burden of reclamation projects, governments can establish regulations and incentives that encourage mining companies to invest in land reclamation (Cao, 2007).
Public-private partnerships and community involvement can also help share the costs and pool resources, making the reclamation process more economically viable. Additionally, investing in research and development of new technologies and techniques can lead to more cost-effective and efficient reclamation methods, reducing the overall financial burden on mining companies and governments.

By deploying strategies that proficiently tackle these challenges, the transformation of tailings ponds and mining lands into agricultural zones could evolve into a more feasible, sustainable solution, offering substantial benefits to the environment, local communities, and food security. In doing so, we can work toward creating a future where reclaimed mine lands provide both economic and ecological benefits, fostering a healthier and more prosperous world for all.

3. An interesting case

We conducted a site visit to Qibaoshan Fe–S Mine in Liuyang City, Hunan Province, China in late 2022 (Yu and Zahidi, 2023b), to examine the progress of its reclamation process and better understand the challenges and opportunities associated with transforming the landscape into a viable agricultural area. From approximately 2000 to 2012, the main mining areas of Qibaoshan Town experienced frequent mining activities and tailings pond discharges, resulting in significant geological damage, land occupation, and damage to vegetation. However, the government has since collaborated with mining companies to implement comprehensive management measures in the mining areas. Our site visit findings showed that the Qibaoshan Fe–S Mine has initiated the process of reclaiming the tailings pond (its No. 1 Tailings Pond) and the adjacent abandoned mining land, with potential plans to repurpose the area for vegetation planting and agricultural use.

The Qibaoshan Fe–S Mine has proactively undertaken measures to promote the reclamation of the mine site and tailings pond land, aiming to “re-green” and enhance soil conditions (as depicted in Fig. 2A). One of their primary initiatives involved the total closure of No. 1 Tailings Pond at the beginning of 2014. After sealing the pond, the Qibaoshan Fe–S Mine implemented a protective barrier membrane over it and subsequently added a layer of new soil. Initially, they planted common plants on a trial basis to evaluate their growth. Following this, they invited research teams to conduct environmental assessments on the reclaimed land, establishing a foundation for the comprehensive transformation of the site into vegetation and agricultural land (as shown in Fig. 2A). Likewise, apart from the No. 1 Tailings Pond, the Qibaoshan Fe–S Mine has initiated trials of cultivating diverse plant types. They are nurturing various species on the reclaimed mining land surrounding the site and meticulously observing their growth (as depicted in Fig. 2B).

The ongoing transformation of tailings ponds and deserted mining sites into vegetation and agricultural lands in Qibaoshan Town is already reaping benefits and promises to deliver even more advantages to the local community. It is setting a precedent for sustainable land use, demonstrating that even areas severely impacted by mining can be reclaimed and repurposed in a way that benefits society and the environment:

- Firstly, the reclamation of tailings ponds and abandoned mining sites has helped to improve the local environment. Planting crops and vegetation helps to restore the ecological balance of the area, reducing soil erosion, and preventing further damage to the land. This also helps to promote biodiversity in the area, which can have positive impacts on the ecosystem. Ultimately, this process will yield extra land for agricultural activities and the cultivation of profitable crops, catering to the rising local demand for food while invigorating the area’s economy.
- Additionally, the reclamation of tailings ponds and abandoned mining sites creates and will create new jobs and economic opportunities in the area. The development of the “ecological economy” will lead to the establishment of new businesses and enterprises, such as ecotourism and organic farming, which will help to diversify the local economy and provide new employment opportunities for the local population. This will not only improve the quality of life for residents but also promote sustainable economic growth.
- Ultimately, this process will yield extra land for agricultural activities and the cultivation of profitable crops, catering to the rising local demand for food while invigorating the area’s economy.

On the whole, the transformation of tailings ponds and deserted mine sites into areas of vegetation planting, land restoration, and sustainable agricultural farming in Qibaoshan Town embodies the potential benefits and opportunities such initiatives can offer. These endeavors, by earmarking additional land for future agricultural production, revitalizing the local environment, and forging new job and economic opportunities, contribute substantially to the enrichment of local communities. Furthermore, they hold the potential to stimulate sustainable economic growth and exemplify the viability of repurposing abandoned tailings ponds and mining sites into valuable assets that serve both environmental and societal interests.

4. Discussion

The prospect of converting tailings pond land for agricultural use is increasingly bright as a growing number of mining companies recognize...
the importance of environmental sustainability and the potential benefits of land reclamation (Ukhurebor et al., 2022b; Guo et al., 2022). It is encouraging to see the governments adopting a more proactive approach in endorsing and regulating this practice. This is being accomplished by providing incentives and assistance to companies that demonstrate a willingness to engage in mine land reclamation projects.

Admittedly, obstacles persist, particularly the high cost and technical intricacy of remediation, as well as potential health risks tied to contaminated soils (Gao et al., 2022). Nonetheless, persistent research and innovation are paramount in surmounting these hurdles, ensuring the safe and efficient reclamation of tailings pond land for agricultural utilization. As mentioned in the text, advancements in technology and the development of more cost-effective methods for soil treatment and land restoration will also play a significant role in overcoming these challenges. Collaboration between mining companies, researchers, and governments will be essential to share knowledge and develop best practices for tailings pond land reclamation. Also, public awareness and support for environmental sustainability can further influence mining companies and governments to prioritize the reclamation of tailings pond land. By emphasizing the long-term environmental, economic, and social benefits of such projects, stakeholders can be encouraged to invest in these initiatives (Robinsky, 2022).

At this juncture, there have been successful instances of reclaiming tailings ponds and abandoned mining lands through environmental technology restoration (Favas et al., 2018; Akimbekov et al., 2022) or land segregation (Yu and Zahidi, 2023b). There are even precedents of employing such reclaimed lands for agriculture (Zhang et al., 2021; Favas et al., 2018; Akimbekov et al., 2022), indicating significant potential for converting tailings ponds and abandoned mining sites into agricultural zones. At the same time, although the transformation of tailings ponds and deserted mining lands into agricultural areas is still in its nascent stages and grapples with numerous formidable challenges, the growing trend towards environmental responsibility and sustainable development is anticipated to catalyze continual efforts to reclaim and repurpose land formerly utilized for mining activities. By surmounting existing obstacles and repurposing tailings pond land for agriculture, we can alleviate the negative environmental impacts of mining. Simultaneously, this opens avenues for sustainable economic growth, bolsters food security, and brings benefits to local mining communities (areas).

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Data availability
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