A Study of Ecological Restoration Indicators of the Brownfields of Shuinandong, Taiwan

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Abstract. The hundred-year prosperity of the mining industry in Jinguashi, Taiwan, introduced the development of new industrial equipment and factory operation models to the settlements of Jinguashi and Shuinandong, and also established a modernized living and social framework. However, changes in global industrial and cultural structures brought on the progression of urbanization, which in turn caused the disuse of abandoned land previously used by the production industry. In the Shuinandong area, the operation of a smeltery polluted the land, damaged the ecology, produced waste and caused the content of heavy metals in the ocean to rise. This environmental destruction continued to impact the natural environment and ecology of the area even after the smeltery closed. Today, with the rise of environmental awareness, people, environmental protection groups and government agencies have begun to pay attention to the impact of “brownfields” around them. In the Shuinandong area, brownfields are mostly used as space for tourism, and not much has been done to restore the environment through ecological methods. Therefore, this study is aimed towards environmental sustainability, and looks at how to preserve the Remains of the Thirteen Levels in Shuinandong while rehabilitating the polluted natural environment and landscapes in the area. This study also establishes ecological restoration assessment indicators that will allow the Shuinandong area to contribute its value for sustainability.

1. Introduction

1.1. Research background
Shuinandong has undergone decades of economic growth and industrial and cultural transformation, and thus its industrial and cultural[1] structure has changed. From 1890 to 1985, gold was discovered in Jinguashi, and its rich mineral fields were found to be worth mining. The area’s mining industry continued to develop under Japanese colonization, and a smeltery was established on the coast in the Shuinandong area. With the changing of the times and industrial structure, Taiwan was no longer reliant on the export of mineral resources from Jinguashi. In the past, industrial development was the main focus, and the importance of environmental protection and sustainability was ignored. Waste water containing large amounts of toxic gas and industrial pollutants was discharged into the ocean by Shuinandong, and resulted in the expansion of the “Yin-yang Sea”, a natural phenomenon originally born from the geological characteristics of the area. The mining industry’s development in the area also caused the pollution of the land and ocean, and resulted in the disuse of abandoned smeltery facilities. Therefore, this exploratory study looks at relevant landscape and ecological conservation theories, industrial ruins, as well as case studies and literature related to ecological preservation and
restoration, in order to explore the assessment factor framework for the restoration and conservation of brownfield environments. This study then summarizes the important indicators that need to be considered for environmental restoration and sustainable development.

2. Literature review

2.1. The formation and definition of brownfield

Brownfields are areas leftover by industrial and economic activity. They began appearing in the first era of industrialization, which was 1800-1914 in the UK, 1870-1940 in Germany, 1900-1970 in most other European countries, and 1877-1980 in the USA [2]. In general urbanization, brownfields were created in the expansion of cities under economic and cultural influences. Brownfields are an irreversible result of early unregulated industrial development. At first, the problem of brownfields did not garner much attention. In recent years, with the rise of environmental awareness, people are now looking more closely at the issue of brownfields. The maintenance and redevelopment of brownfields can not only provide financial income and job opportunities for locals, but also facilitate healthy socio-economic and environmental development, bringing both economic and environmental benefits [3]. Brownfields are often accompanied by urban structural changes, industrial restructuring, and environment pollution. Disused, underused or misused brownfields caused by industries migrating overseas has major impact on urban development. Taiwan’s aggressive development of secondary and tertiary industries in the past decades resulted in many pollution incidents and polluted sites. Looking at the nature of Taiwan’s industrial development and the characteristics of its brownfields, the main difference between the brownfields of Taiwan and those in other countries lies in its scale and location. Most brownfields in other countries are larger in area, with entire cities being potential brownfields. In Taiwan, brownfields are usually hidden in individual factory land or disused land on the edges of urban development areas. The definition of these brownfields are as seen in Figure 1.

Therefore, according to the above analysis, brownfields are remnants of industrial and economic activity, and can be accompanied by issues such as pollution, disuse and underuse, which result in many deteriorating sites [4]. In other countries and regions such as the European Union and China, brownfields have been extensively discussed and researched, whereas in Taiwan such research is uncommon and limited to basic concepts and exploration.

![Figure 1. The research architecture to construction of indicators for sustainable development of cultural landscape in Chung Hsing New Village, Taiwan.](image-url)
2.2. Redevelopment of brownfields

The existence of brownfield can cause the breaking up of urban space and disappearance of urban functions, as well as result in waste of urban development resources, increase in crime rates, economic depression, pollution, and other problems. Therefore, the aim of brownfield sustainable redevelopment approach is to incorporate urban spatial development restoration and functions to benefit urban public facilities and improve disaster prevention capabilities, while fulfilling current and future economic and social needs. The “European Urban Environmental Brownfield Sustainable Development Plan” describes brownfield sustainable redevelopment as using an approach that manages and restores usage of land, in order to ensure humanity’s current and future needs under acceptable conditions for sensitive environments and robust socio-economic systems. The benefits of brownfield redevelopment releases pressure of overconsumption of lands and re-utilizing lands, stimulates economic revitalization and growth, and improves social environment quality, while having a positive effect on the ecological environment and human health [5]. Consolidation of various researchers’ opinions of brownfield redevelopment features is as seen in Figure 2.

Figure 2. Sustainable redevelopment of brownfields.

2.3. Ecological restoration

The term “ecological restoration” includes the rehabilitation of forests, oceans, wetlands and other natural environments. Existing ecological rehabilitation structure frameworks are built up with full-sided, completed, and combined aspects indicators. By creating or restoring a historic environment yet excluding its initiative ecosystem function, the functions/approaches are just artificial structures which do not convey the ‘restoration’ feature. Thus, the term ‘restoration’ should include the restoration of human historic heritage and natural environments.

3. Methodology

This study, through literature review, interviews, case evaluation and analysis, constructs the reviewed regeneration evaluation frameworks of brownfield, and applies the Analytic Hierarchy Process (AHP) to analyze the relative weights between the indicators. Furthermore, the study, through in-depth interviews with experts in various relevant fields, explores their opinions and advice on brownfields redevelopment methods, in order to benefit the follow-up study of the brownfields environment sustainable development and development assessment indicators to establish reference.
4. Industrial ruin ecological restoration case studies

4.1. Germany ruhr industrial area
The Ruhr industrial area carried out “green space planning” with ecological restoration, and created a “water cleaning and circulation system” and “flood water drainage system”. Their methods included sewage filtering and rain water collection, wind energy usage, industrial waste utilization, vegetation protection and soil purification. By building the world’s largest sewage treatment plant, they removed mud, heavy metals and other toxic substances from the water, and then released the clear, clean water back into the river. They focused on re-purposing disused factory facilities, revitalizing polluted rivers and land, and restored most of the land to the farms or natural forests it originally belonged to before industrialization. They took an “autogenic succession” approach to environment rehabilitation, in order to heal the land after industrialization. Their methods are as presented in Table 1.

| Restoration Methods                      | Method Description                                                                                           |
|-----------------------------------------|-------------------------------------------------------------------------------------------------------------|
| Sewage filtering and rain water collection | Establishing a bio-sewage treatment plant and utilizing micro-organisms to purify river sewage               |
| Using wind energy                       | Utilizing wind energy to form a water recycling circulation program such as pumping and discharge purified water through water channel to the higher landscape for dry season irrigation; then restoring additional waters into overflow retention tanks during the wet season. |
| Reusing industrial waste                | Utilizing industrial waste residue to pave roads, city squares, and rebuild clean river beds                  |
| Plant protection                        | Selecting indigenous and foreign organic plants, and taking an “autogenic succession” approach to environment rehabilitation, in order to heal the land after industrialization. |
| Soil Purification                       | Removing polluted soil within a 2.5 meter depth, burning it and then refilling with new soil.                 |

4.2. The USA. gas works park in seattle k
Gas works park in Seattle took a “cleaning and greening” approach, and carried out a “biotech plant remediation plan”, with methods including soil purification, improvement of the ecosystem through natural systems, plant choice, reuse of derelict industrial space and recycling of energy and materials. They also transformed existing industrial remnants from old and disused plants and machinery into facilities with aesthetic value. Following the principle of “minimal intervention and self-recovery”, and placing emphasis on site history, they preserved the industrial heritage in their designs, and achieved harmony between humanity and nature. Their methods are as presented in Table 2.

5. Ecological restoration strategy and indicator establishment

5.1. Ecological restoration assessment
This study reviews and analyzes relevant literature and uses the definitions given by The Society for Ecological Restoration (SER) to explore ecological integration, including bio-diversity, ecological process and structure, territorial and historic transformation, persisting environmental practice. This study finds that the ecological restoration of brownfields can be categorizes in to 3 aspects, “environment rehabilitation”, “water revitalization”, and “soil purification”. The methods are as presented in Table 3.
Table 2. The USA restoration methods of gas works park in Seattle

| Restoration Methods                          | Method Description                                                                                                                                                                                                 |
|---------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Soil Purification                           | Analyzing the contaminant substances and introducing enzymes that can break down contaminants and increase natural bio-organism nutrients in the soil. Utilizing biological and chemical reactions to clean the polluted area. |
| Improvement of the ecosystem through natural systems | Using a natural ecological system instead of expensive technological techniques to prevent pollution.                                                                                                               |
| Plant choice                                | Choosing quick-growing, highly adaptable plants with high survival rates, with the priority being nitrogen-fixing plants that can improve the soil.                                                                |
| Reusing derelict industrial space           | Reusing existing discarded resources to revitalize the space while paying attention to the history of the site. The designs preserved the industrial remains.                                                          |
| Reuse                                       | Respecting the historic heritage and landscape and ecosystem development of the site when redeveloping the derelict remains. Recycling materials and energy as much as possible during the design process. |

Table 3. Ecological restoration assessment chart

| Assessment Aspects         | Description                                                                                                                                                                                                 |
|----------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Environment Rehabilitation | Restoring the environment to its natural state prior to over-mining, and investigating suitable vegetation to use as the basis for restoration. Attracting animals to live in the area with vegetation and respecting the process of natural regeneration, in order to restore the original ecological state of the area. |
| Revitalizing Water Resources | Using the activity of plants, animals or micro-organisms to treat sewage, and redeveloping industrial water channels into natural rivers, to facilitate their natural regeneration. This can accelerate the metabolism of metals and increase river activity, in order to help the restoration of plants and animals. |
| Soil Purification          | Focusing on the improvement of heavy metal pollution by planting vegetation that is able to absorb the toxic substances, and gradually cleansing the pollution through biological and chemical means, in order to stabilize metal content in the soil, lower its activity and remove it from the food chain, and gradually improving soil conditions. |

5.2. Industrial ruin ecological restoration indicator establishment
From the above assessment aspects, we will infer and analyze factors using literature and cases. Meanwhile, we conducted interviews and discussions with various experts, and consolidated 12 assessment indicators, as described in the following:

5.2.1. Environment rehabilitation indicator
Ruin greenery treatment: treating and maintaining the plants and landscapes on the walls and roofs of the Remains of the Thirteen Levels.

Choosing coastal nitrogen-fixing plants: respecting the process of natural regeneration and protecting the indigenous flora of the site. Choosing quick-growing, highly adaptable plants with high survival rates, with the priority being nitrogen-fixing plants that can improve the soil.

Greening the environment: covering the natural soil layers with large expanses of vegetation, integrating it with underground soil layers and allowing animals and plants to grow.

Land biodiversity: choosing plants that can attract butterflies and birds, and structuring the plants in three tiers (upper growth, undergrowth and ground cover). This provides an environment for organisms at the bottom of the ecological pyramid to survive in, and ensures a balanced ecological environment for low-level organisms such as toads, centipedes and moss and fungi growing on dead trees. It also provides high-level organisms with ample food sources, and can help increase environmental biodiversity.

5.2.2. Water resource revitalization indicator.

Renovating artificial river channels: renovating and reusing earlier artificial river channels of the smeltery to create a local drainage system, and lessen the metals naturally discharged into the ocean.

Water retention: creating new river channels into the ocean, using non-polluted river channels as the basis for water circulation, in order to create new backwater as well as decrease and control the amount of backwater from the old, polluted river channels.

Sewage recycling and filtering: including the sewage from the artificial channels of the Remains and sewage polluted by heavy metals. Creating a complete sewage treatment system, allowing the substances and energy of the site to be recycled and reused.

Water biodiversity: cross-interaction between the river corridor, trough and mouth form an ecosystem; the quality of the river corridor reflects the river bed’s biodiversity and water quality, forming a diverse water habitat.

5.2.3. Soil purification indicator

Renovation of derelict facilities: decreasing the number of old, derelict industrial facilities by demolition or adding creative artwork, in order to improve the area’s landscape.

Reusing waste: waste will pollute the soil if buried in the earth without proper treatment. The impact of waste on the environment needs to be lessened, and reusing materials follows and eco-friendly principle and can further improve the quality of the living environment.

Plant rehabilitation: Utilizing plants to absorb heavy metals from contaminated soil, and then recycling the heavy metal elements, in order to reduce the contaminations of the soil.

Improve soil contamination levels: using micro-organisms and biotherapy to treat contaminated soil, in order to improve the contamination levels in the soil, change the activity of the heavy metals, and decrease the harm caused.

5.3. Indicator weighting analysis

This study uses expert surveys and AHP statistics analysis. Participants in the surveys came from industrial, government, and academic backgrounds, and all had abundant understanding and knowledge on urban brownfield redevelopment, ecological restoration, and industrial ruins & environmental landscape planning. Of the 17 surveys conducted, 14 were valid, and three were invalid. The weighting analysis of each assessment indicator item is as follows in Table 4.
Table 4. Analysis of the weight of environmental sustainability indicators.

| Assessment Aspects | Assessment Indicators                  | Relative Weight | Relative Rank | Absolute Weight | Absolute Rank |
|--------------------|----------------------------------------|-----------------|--------------|-----------------|--------------|
| Environment        | Ruin greenery treatment                 | 0.1876          | 4            | 0.0559          | 11           |
| Rehabilitation     | Choosing coastal nitrogen-fixing plants| 0.2523          | 3            | 0.0752          | 8            |
| 0.298              | Greening the environment               | 0.2631          | 2            | 0.0784          | 9            |
|                    | Land biodiversity                      | 0.2970          | 1            | 0.0885          | 4            |
| Water Resource     | Renovating artificial river channels    | 0.2151          | 3            | 0.0785          | 6            |
| Revitalization     | Water retention                        | 0.1499          | 4            | 0.0547          | 12           |
| 0.365              | Sewage recycling and filtering         | 0.3203          | 1            | 0.1169          | 2            |
|                    | Water biodiversity                     | 0.3148          | 2            | 0.01149         | 3            |
| Soil Purification  | Renovation of derelict facilities      | 0.2436          | 2            | 0.0821          | 5            |
| 0.337              | Reusing waste                          | 0.1754          | 4            | 0.0591          | 10           |
|                    | Plant rehabilitation                   | 0.2312          | 3            | 0.0779          | 7            |
|                    | Improve soil contamination levels      | 0.3499          | 1            | 0.1179          | 1            |

6. Conclusion

6.1. The impact of brownfield rehabilitation on Taiwan

This study found out about the formation of the brownfield at Shuinandong through literature review and expert interviews, and discussed the impact of brownfield rehabilitation on Shuinandong. While Shuinandong’s land area is limited, but the smeltery and mining industry in the area achieved much progress in the development of industry in the Jinguashi and Shuinandong area, and helped lay the foundation for Jinguashi as a mining village. However, as the times and industry structures changed, the mining industry began to face challenges such as industry decline and export transformation. The remaining ruins and polluted brownfield left by the mining industry has had impact on the life of local residents and the ecosystem which needs to be carefully considered, and the rehabilitation of the land must take an environmentally friendly, low pollution and sustainable approach. The location and development of brownfields will influence urban development, and therefore each piece of land should play a suitable role and serve a purpose. Thus, the rehabilitation of the Shuinandong brownfield should not only focus on the impact to the living standards of local residents, the improvement of environment quality, and the solution to pollution. It should also carefully contemplate a new approach to land rehabilitation in its environmental landscape and ecosystem planning, in order to increase the revitalization brought by brownfields to the area, and facilitate sustainable development of the ecosystem.

6.2. Industrial ruin ecological restoration indicator methods

- Improve soil contamination levels: the environment rehabilitation methods should take two main approaches: the first is to change the form of existence of heavy metals in the soil by changing its activity and oxidation levels, in order to lower its transferability in the environment and usability by organisms; the second is to remove or neutralize the heavy metals in the soil through various means. The best method is to dig up the polluted surface soil, and treat it with bioremediation methods by using micro-organisms in the soil to absorb, neutralize, oxidize and reduce heavy metals, in order to lower its toxicity and avoid its harmful impact on the food chain.
- Sewage recycling and filtering: adding a heavy metal filtering system in natural river channels, so as to reduce the amount of heavy metals discharged into the ocean, and to separate the polluted areas with the rivers. Using micro-organisms to neutralize the activity of oxidized...
heavy metals in the river bed, in order to prevent negative impact on the ecological quality of water bodies and the food chain.

- Water biodiversity: segregating the river mouth leading to the “Yin-yang Sea” area and transferring the organisms from areas with high heavy metal levels, and creating porous and undisturbed habitats with multi-layered biodiversity for small organisms along nearby coasts, in order to rehabilitate indigenous species and achieve sustainability for the marine ecosystem.

- Land biodiversity: creating a porous environment with undisturbed, multi-layer greenery, providing a habitat small organisms while creating a bio-diverse base with a range of indigenous, bird and butterfly attracting plants and surface soil protection.

- Renovation of derelict facilities: there are two main sustainable methods to re-purpose the old buildings: the first is to completely demolish the derelict facilities and restore the land; the other is to change the appearance of the derelict facilities, using cultural and artistic methods to decorate and transform its appearance, and breathe new life into the local culture.

- Renovating artificial river channels: using existing artificial river channels as a basis for renovation to block the heavy metals that exist in the natural environment, in order to change and control the impact of heavy metals on the environment at the river mouth.

- Plant rehabilitation: using plants to absorb and convert the polluted area, and change the activity of heavy metals, in order to prevent the spread of the contaminants to the surrounding neighborhoods and environments.

- Choosing coastal nitrogen-fixing plants: nitrogen fixing is a way for nutrients to circulate. Many plants are capable of fixing nitrogen, and can retain nutrients to enrich the soil, which will benefit the nurturing of other organisms and balance the severe ecosystem. The coastal nitrogen-fixing plant of choice that can withstand salt and winds is the Australian pine tree (Casuarina equisetifolia).

- Greening the environment: The Remains, apart from the building surfaces, should be kept as greenery. Vegetation that can withstand the salt and winds should be planted in coastal areas. Using a diverse range of species to achieve multi-layer greening functions due to the restrictions of the environment.

- Reusing waste: choosing uncontaminated bricks, industrial waste and mining by-products, and reusing them as far as possible to revitalize the area.

- Ruin greenery treatment: as the Remains have been abandoned for a very long time, the overgrown greenery needs to be organized and maintained, in order to preserve the beauty of the Remains. Using perennial vine plants to climb the Remains and increase the area of greenery.

- Water retention: increasing soil area to enhance direct seepage of rain water. Using soil land to plant greenery is also the most natural and eco-friendly water retention design.

7. References
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