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Wind tunnel study of odor impact and air ventilation assessments for relocating sewage treatment works to caverns

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ABSTRACT

In recent years, the topicality of environment-related issues has been frequently emphasized in terms of sustainability and the better management of development in harmony with the environment. As for Hong Kong, one of the most densely populated cities, the scarcity of land has always been assumed as a major impediment for its long-term development. Therefore, the Hong Kong government actively explores approaches to enhance usable land resources. One viable approach is rock cavern development.

This paper presents a feasibility assessment of relocating a sewage treatment works to a cavern, with emphasis on the evaluation of environmental sustainability. Wind tunnel tests were carried out with efforts to estimate the prospective odor impact, as well as the wind availability at pedestrian level. It is noted that the sewage odor concentration depends greatly on the dispersion distance and the surrounding topography. The results indicate that when the sewage treatment works is relocated to the cavern, the predicted odor concentration will not cause damage to human health as long as the ventilation shaft is properly placed. In addition, the air ventilation assessments were conducted for both before/after the planned building development. It shows that the new building development at the current plant site will not significantly influence the wind availability at pedestrian level in the surrounding areas.

This paper highlights the importance of sustainable development in connection with the environment, and shows that rock cavern development can be an attractive alternative for strategic urban planning in Hong Kong.

1. Introduction

Sustainable development has gradually become, and certainly will continue to be a prevalent topic that attracts worldwide attention. It was officially defined as “development that meets the demands of the present without compromising the ability of future generations to meet their own needs” (WCED, 1987). Essentially, sustainable development is a broad term that comprises a variety of issues that are pertinently related to the long-term development of society. Over the past few decades, many countries and regions have experienced booming economic development. However, it is unfortunate to observe that environmental conditions sometimes have degraded considerably in parallel with the rapid economic development. Consequently, the 1992 United Nations Conference on Environment and Development officially acknowledged the importance of sustainable development and established a specification that consideration of socioeconomic and environmental issues should be fully integrated into strategic development planning and policy (UN General Assembly, 1992).

As for Hong Kong, the imperativeness to pursue sustainable development is incontestable. Hong Kong is well known as a world-class financial center and renowned tourist attraction, which leads to a rapid augmentation of population in the past few years. The population of Hong Kong has reached 7.15 million in 2012 and it continues to grow at an average annual rate of 0.7% (ISD HKSAR, 2013). Hong Kong has a land mass about 1104 km^2 and less than 25% of the area is developed due to the complexity of geography and governmental policy (GovHK, 2014). Given the above information, Hong Kong is undoubtedly one of the most densely populated cities in the world. The concentrated distribution of the population has deservedly gained benefits with respect to public transport, efficient land utilization and infrastructure construction, etc. Nevertheless, it concurrently reveals difficulties for urban designers to maximally absorb the advantages of the natural environment, for instance, sunlight and natural air

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ventilation (Ng et al., 2004). These features, in some cases, may diminish the achievability of a favorable living condition.

The Hong Kong government is confronted with a number of environment-related difficulties, one of which is the inadequate land supply. Due to the characteristics of hilly topography, the capacity of usable surface land in Hong Kong is extremely limited and it has been identified as a major impediment that prevents Hong Kong to develop steadily. Under the circumstances, the Government actively explores approaches to minimize the disadvantage and strengthen the land supply. In 2011, a feasibility study titled “Enhanced Use of Underground Space in Hong Kong” was completed by the Government, in which a number of governmental facilities were selected to demonstrate the wide adoptability and viability of cavern development in Hong Kong (CEDD HKSAR, 2011).

Meanwhile, another noticeable environmental problem in many cities such as in Hong Kong, which intensively impacts residents’ daily life, is the unfavorable air quality. The perniciousness of air pollution has been reported constantly and the reduced air quality has gradually become a major menace to the public health in Hong Kong (EB HKSAR, 2013). Regardless of the increasing motor vehicles and local power plants, the inadequate porosity and penetrability in urban fabric are generally considered as the major problem that account for the undesirable air environment. Low speed wind or stagnation is often experienced on the street of Hong Kong, which is partly attributed to the inadequate wind permeability in urban design. The densely distributed high-rise buildings inevitably obstruct the wind from penetrating into deep urban canyons, resulting in accumulation of air pollution. Due to the growing awareness of achieving a favorable living condition, the local government has undertaken a series of initiatives to targetedly ameliorate the current conditions.

2. Review

2.1. Background

To support Hong Kong's sustainable development, a feasibility study on the relocation of a sewage treatment works to the nearby cavern was suggested, which aims to release the existing site for housing construction. As stated in the feasibility report, the nearby mountain named Nui PO Shan, which has a distance of 2 km to the current plant site, was preliminarily selected as the relocation site. This selection integrates the consideration of various factors, including the geological conditions, the land ownership, as well as the impacts on the surrounding environment, nearby traffic network, and the existing sewerage system. Fig. 1 shows the geographic location of the targeted plant site. This paper presents the environmental impact assessments of the proposed project, with emphasis on evaluating the prospective sewage odor impact to the neighboring communities. Furthermore, the air ventilation performance in the proposed residential area is assessed in accordance with the governmental speficiations. Firstly, a brief literature review is addressed to illustrate some key aspects that are considered in this study.

2.2. Rock cavern development

The topographic characteristics of Hong Kong are generally described as hilly and mountainous, which demonstrates enormous potential for rock cavern development. It was reported that about 64% of Hong Kong's land is suitable for developing rock cavern (Roberts et al., 1997). Undoubtedly, for most rock carven developments, the higher capital costs and extra costs for lighting and ventilation will decrease its adoptability comparing with traditional surface ground developments (Zhao et al., 1996). However, on the other hand, the usage of cavern exhibits predominance in

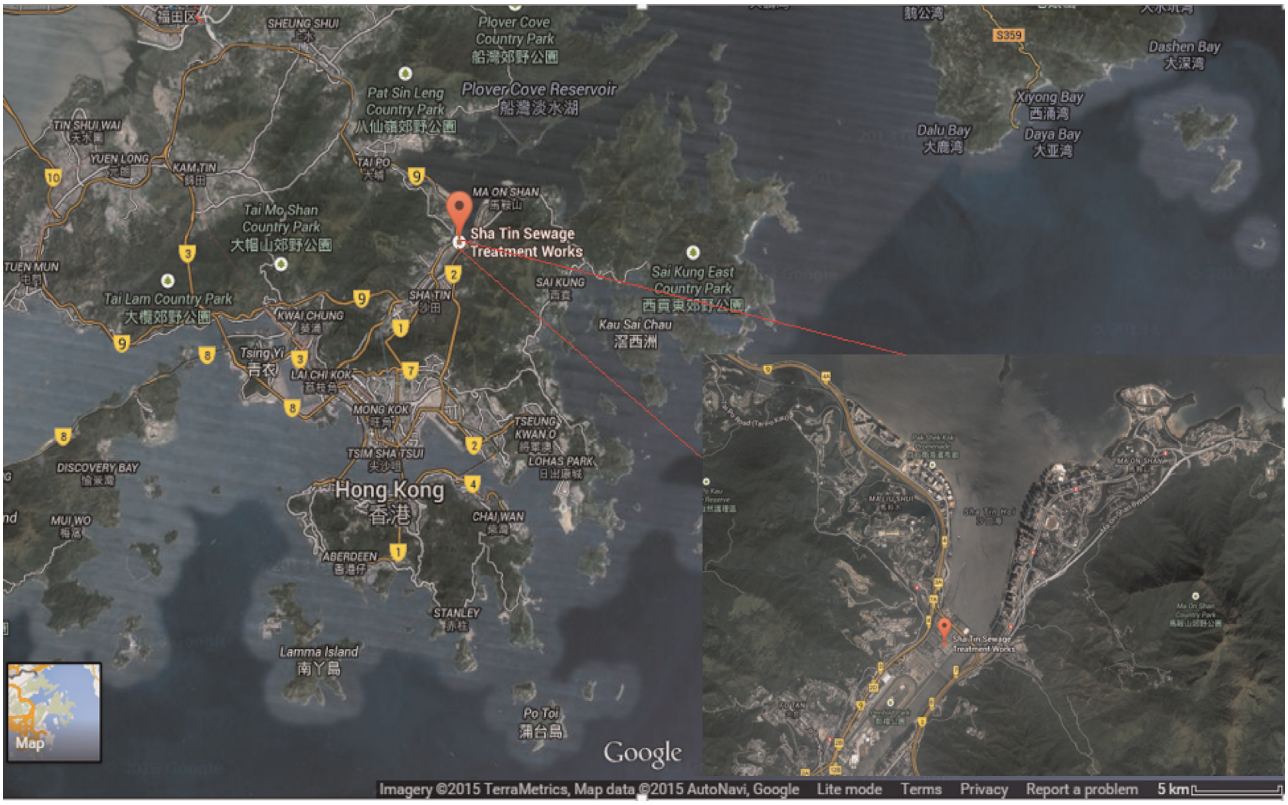

Fig. 1. Geographic location of the targeted plant site.