

VI.4

Municipal landfills. A case study: remediation and reclamation at Nanji Island

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VI.4.1. Introduction and background

The Nanji Landfill, located on Nanji Island in the Seoul Metropolitan Area, South Korea (Fig. VI.4.1), is considered to be one of the largest landfills in the world. The landfill comprises a surface area of nearly two million (1,760,000) square meters (Nanji Island comprises three million square meters) and reaches an elevation of 75 m. Landfilling operations commenced in 1978 and ceased in 1992. At least at the beginning of landfilling very few limitations existed regarding materials that could be dumped. It appears that landfilling initially started on Nanji Island as a flood protection measure. The nature of the municipal solid waste at that time was predominately in the form of coal ash and fill collected from construction sites. The industrial boom, which South Korea experienced in the 1980s profoundly, changed the nature of the solid waste as well as increasing its volume (Fig. VI.4.2). In 1990, solid waste per capita had reached 2.2 kg/day that represented the highest in the world (Park et al., 1994). In addition, there are indications that during this time, industrial wastes were often mixed with the municipal solid waste and landfilled, as there were no other alternatives at that time. Records were not kept.

The landfill, at present, poses an immediate chronic environmental threat to the local populace although immediate acute risk is minimal. The landfill is covered with soil so that airborne transport is minimal. The landfilling operations started, however, without a leachate control system, which is standard practice today. Hence, it is not unique among older landfills. Koo and Yoon (1994) showed that leachate generated in the landfill from infiltrating precipitation percolates through the underlying sand layer and contaminates the underlying groundwater.

Hydrogeological data around Nanji Island is limited (Koo and Yoon, 1994). In similar cases, however, mounding of the groundwater table in landfills can affect changes in the natural groundwater flow patterns. Thus, percolating leachate may not only be affecting underlying groundwaters but may also be affecting the quality of the local surface waters, especially if these are fed by the groundwater. As a result, in 1993 the Seoul City's water intake was moved to a site far enough upstream of the head of tide on the Han River to eliminate the threats caused by the leachate and the contaminated tributary near Nanji Island.

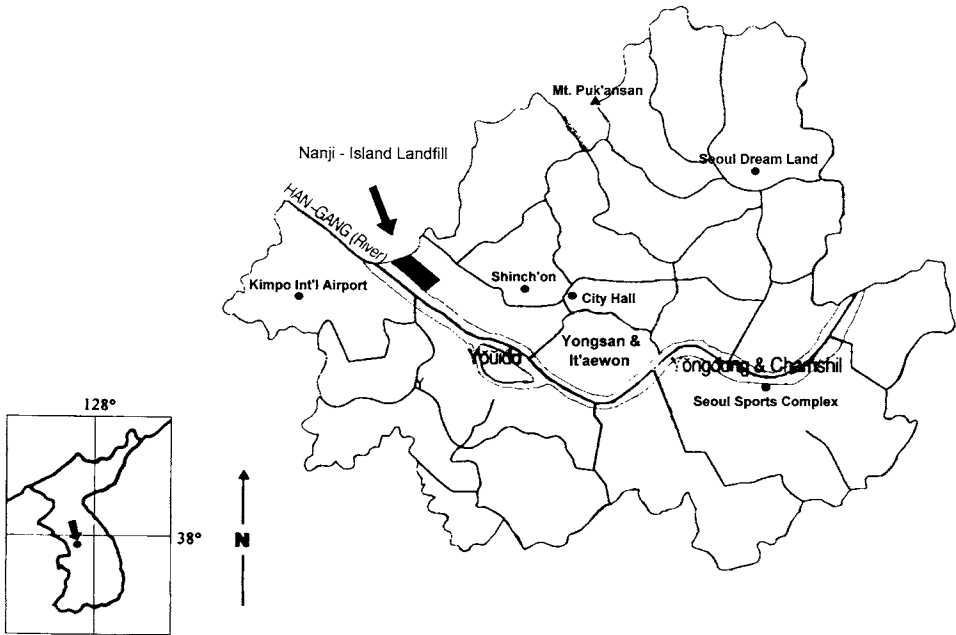


Figure VI.4.1. Location of Nanji Island Landfill in the City of Seoul.

Attention has recently been focused on Nanji Island from concerns other than purely environmental. An estimated 15 million people live within the Seoul Metropolitan Area. Available land in this area has become extremely scarce and, thus, valuable. The landfill is in close proximity (10 km) to downtown Seoul. Nanji Island is being considered as an

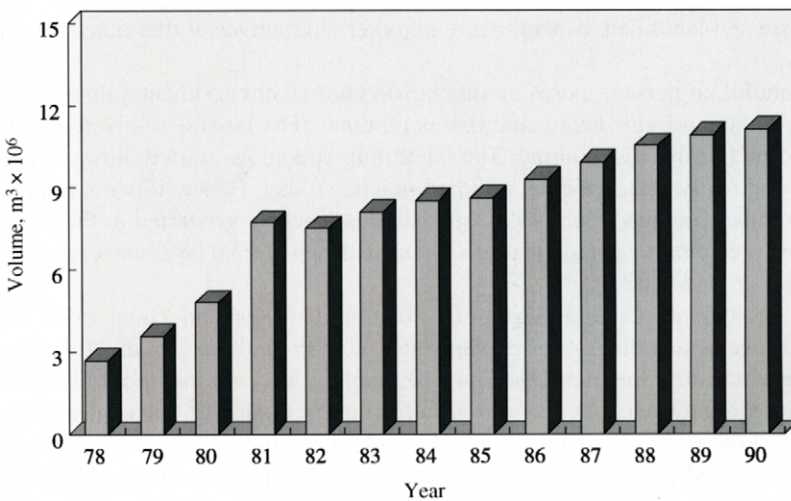


Figure VI.4.2. Solid waste volume generated versus time.

extremely valuable piece of real estate. The presence of the landfill represents a serious impediment to development. A rather singular problem is posed: can a serious environmental condition be mitigated in such a fashion that the cost be offset by potential resource recovery? This case study will discuss some of the issues, which must and are being considered.

VI.4.2. Environmental problem definition

If left as is, even if no further solid waste is input to Nanji Island, the landfill will still represent an environmental threat to the local populace. Covering and vegetating will and has seemingly closed off one of the sources of environmental risk, namely blowing of solids offsite and transport by birds. However, the anaerobic decomposition endemic to sanitary landfills produces methane and other gases, which can not only contribute to air pollution but also ignite and burn (Vesilind and Rimer, 1981). In fact, the Nanji Landfill was burning in 1993 when the authors inspected it during a field investigation. Finally, hazardous industrial wastes, which may be present in the landfill, may be ignitable (Michaels et al., 1986) or reactive, generating toxic gases (Handy et al., 1986). Numerous complaints of headaches, vomiting and respiratory ailments have been registered by nearby residents (Daewoo Engineering, Inc., 1992). It is well known that infiltration percolating through landfills can generate leachate, which can contaminate underlying groundwater (Khanbilvardi et al., 1987). Another, not so obvious potential problem, is that of groundwater mounding which can cause localized reversals of flow direction. This phenomenon is illustrated in Figure VI.4.3. This figure also shows that the hydraulic gradients in the vicinity of landfills can be increased by mounding, thus increasing the groundwater flow rate. If the natural direction of the groundwater is toward the stream, some of the contamination would be expected to reach the stream. Since the Nanji Landfill does not have a leachate collection system, one would expect leachate to contaminate both the groundwater and the Han River. Recently, several groundwater wells adjacent to the landfill were closed due to leachate contamination. These wells had been used for drinking water and farm irrigation since before the landfill. Koo and Yoon (1994) investigated groundwater contamination by inorganic compounds around the Nanji Landfill. Kaur et al. (1996) tested the toxicity of the Nanji Landfill leachate using the Japanese Medaka Embryo Larval Assay. Water samples from surface waters proximate to the landfill did not exhibit toxicity, even at 100%. The leachate, however, was found to exhibit extreme toxicity. At least at present, it thus appears that the leachate entering the surface waters is being sufficiently diluted. This could, however, change.

VI.4.3. Site remediation/reclamation

One of the challenges facing potential remediation of the landfill site is its heterogeneous nature. A study conducted by Daewoo Engineering, Inc. (1992) reported results of test borings drilled at the apex of the landfill and some of these results are presented in Figures VI.4.4–VI.4.6. Figure VI.4.4 displays percent combustible and non-combustible matter versus depth. The upper 15 m shows approximately 45–55% of each while deeper

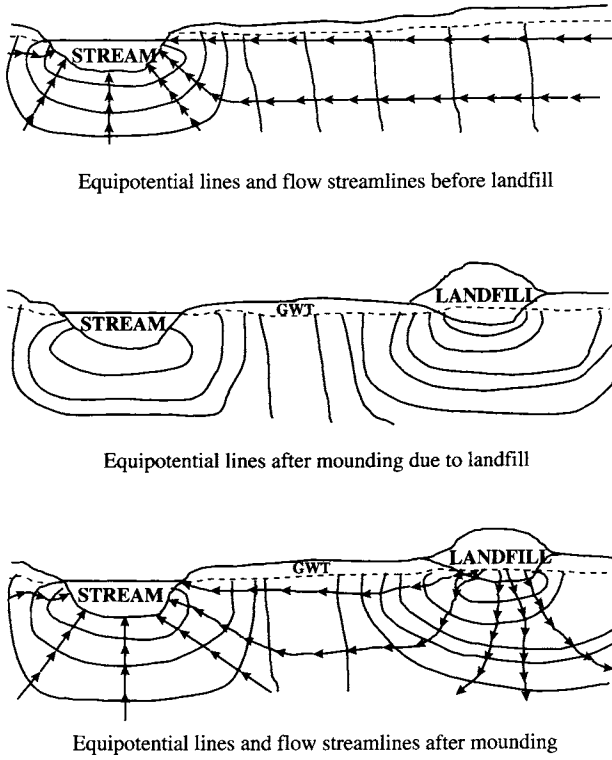


Figure VI.4.3. Groundwater table mounding resulting from landfill.

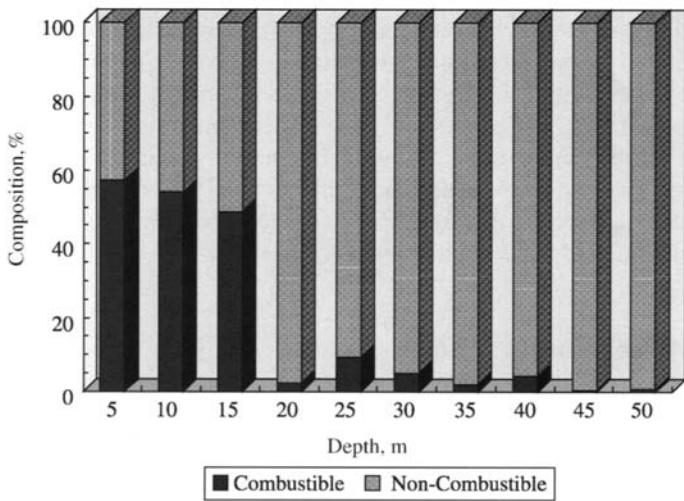


Figure VI.4.4. Combustible and non-combustible matter versus depth.

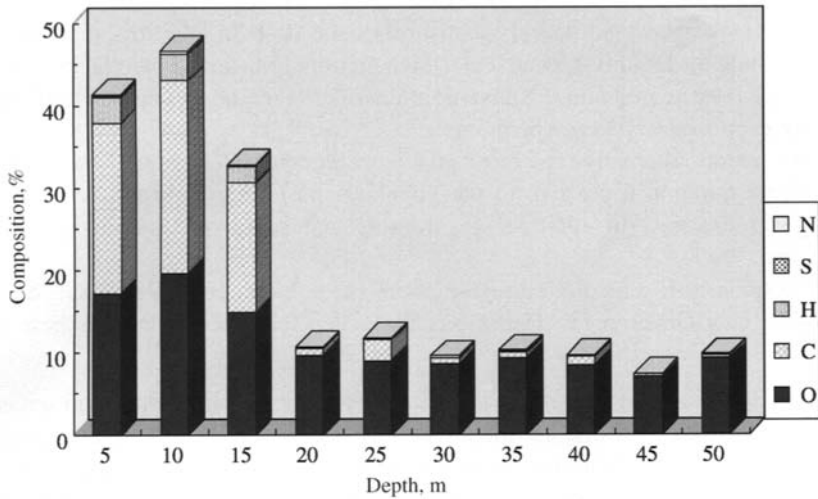


Figure VI.4.5. Composition of Nanji Landfill versus depth.

the amount of combustible matter falls off dramatically to less than 10%. Figure VI.4.5 shows that much of the deeper inorganic matter is ash. Finally, a partial elemental analysis displayed in Figure VI.4.6 shows that the combustible matter is primarily carbon, hydrogen and oxygen (as expected). These figures underscore the dramatic change in the nature of the landfilled materials over time.

Several alternatives are available to address the Nanji Island Landfill Site. These range from no action to remediation and reclamation of the land. The remediation/reclamation alternative is extremely challenging, however, it is thought that the potential real estate

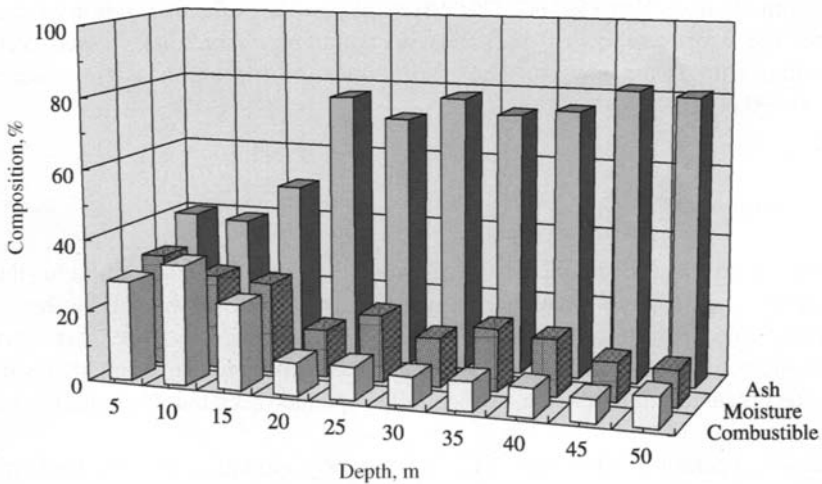


Figure VI.4.6. Elemental composition of Nanji Landfill versus depth.

value of the reclaimed land would greatly offset the cost. In addition, it must also be remembered that the landfill is located in a large metropolitan area. Potential human health risk resulting from remediation/reclamation activities must be considered and, in some cases, may even severely limit operations.

The no action alternative is most likely unacceptable. Although the landfill at present offers minimal acute risk to the populace, no such conclusions can be drawn regarding chronic risk. In addition, gas venting and subsurface burning present real potential risk.

Four options for remediation/reclamation have been considered by the Seoul Metropolitan City Government (Daewoo Engineering, Inc., 1992). Each of these will be described.

1. *Landfill mining*. In this option, the landfill materials will be excavated and screened to separate inorganic and organic materials. Organic materials will be composted and inorganic materials will be transported to and landfilled at another site. This type of remediation has been successfully performed at several sites in the United States. The cost estimate for this option is approximately US \$860,000,000.
2. *Solidification/resource recovery*. This option involves excavating the landfill solids and then mixing the solids with cement. Blocks are then formed which can be used for building materials. The cost estimate for this option is approximately US \$7,700,000,000. It is important to note that the resultant blocks may be sold, thus recovering some of the cost.
3. *Bioremediation*. This option involves enhancement of the natural microbial degradation processes occurring in a sanitary landfill. This involves the introduction of nutrients and an electron acceptor to enhance anaerobic microbial activity. The by-product methane gas can be vented and taken to minimize the potential of slope failure. Another drawback is that the landfill material is highly heterogeneous. The cost estimate for this option is approximately US \$61,000,000,000.
4. *Excavation and movement to a new site*. An alternative site is currently being used several miles from Nanji Island. This alternative involves the excavation of the Nanji Island Site with transport of the solids overland (by either truck, closed conveyor, railroad or ship) to the new site. The cost estimate for this option is approximately US \$7,700,000,000.

VI.4.4. Summary

The Nanji Island Landfill situation is representative of environmental problems that face many rapidly industrializing nations today. Initially, landfilling operations had started without any consideration of environmental concerns. During the 10 years of operation, however, the volume increased and nature of the material changed in dramatic fashion. To further exacerbate the situation, the city spatially expanded such that the landfill is near the center of town.

Landfilling operations were initiated as a flood protection measure. The land on which the landfill is situated has a potentially high real estate value. The projected value of the land could help offset the cost of remediation/reclamation. A number of technologies are

being considered. This site, pending successful remediation/reclamation, could be transformed from an unfortunate environmental disaster to a success story of great proportions.

Acknowledgements

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