Current issues at the South Fremantle landfill site, Western Australia

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Abstract

The South Fremantle Landfill site operated between the years of 1931 and 1986 and received a wide range of domestic, industrial and other hazardous waste. Remediation was inadequate at the time of closure, consisting only of covering the waste with a thin capping layer of sand. A caravan park was then built in the southeast corner of the site. Investigations over the last 20 years have highlighted a number of problems with the site including landfill gas production with the potential for explosion, groundwater contamination, settlement of the waste and other health hazards associated with hazardous waste. The recent Contaminated Sites Bill has focused renewed attention on the potential options for the rehabilitation of the site, all of which are likely to involve significant expense. A feasible management option employing the use of a geomembrane to cap the waste and act as a gas blanket to create a preferred migration path for the gas into a collection system is proposed. It is asserted that the site is unsuitable for residential development, although this is an option being considered by the Council to raise funds for the remediation work.

Keywords: landfill, remediation, waste, gas, groundwater, leachate.

Introduction

As a nation, Australia produces large quantities of waste per capita and this has progressively increased over recent time to reach an unprecedented level across all sectors of the community. This presents a significant management issue since the disposal of solid waste has associated environmental, economic and health impacts. A number of options are available for the disposal of waste. These include waste minimization, recycling, materials/energy recovery, treatment and landfill disposal. Sanitary landfill remains the principal means of solid waste management in Australia, despite growth in other areas of waste management (Sinclair Knight 1991). Landfill is the cheapest option financially and deals with the widest range of materials. Other methods accept only a limited range of wastes and still require landfills to dispose of residues and other wastes (Sinclair Knight 1991). Landfill sites create a number of issues and problems which may persist long after dumping has ceased. Many landfill sites which are now closed were created and operated at a time when there was minimal understanding of their potential impact on the environment. There were few or no controls on the dumping of waste and little or no rehabilitation of landfill sites. However, as Albert Einstein once said, “today’s problems cannot be solved by thinking the way we thought when we created them".

This investigation focused on problems currently being faced at the South Fremantle landfill site, located south of the City of Fremantle in Western Australia. The landfill received domestic and industrial wastes during the period 1931–1986. The site was then partially covered by clean sand and left largely unremediated (Environmental Health Department, City of Fremantle 1990). The site has been the subject of concern by the local council, local residents and the media for a number of years and has recently received renewed media attention regarding management options for the site.

The following list includes some of the potential risks associated with landfill sites (City of Fremantle Council 2001).

- Instability of the ground as waste consolidates
- Soil contamination
- Groundwater contamination
- Landfill gas production – odors and fire hazard
- Fire risk in the waste materials
- Adverse health effects associated with hazardous waste
- Greenhouse gas emission (landfills are thought to be the source of 10% of greenhouse gas emissions in Western Australia).

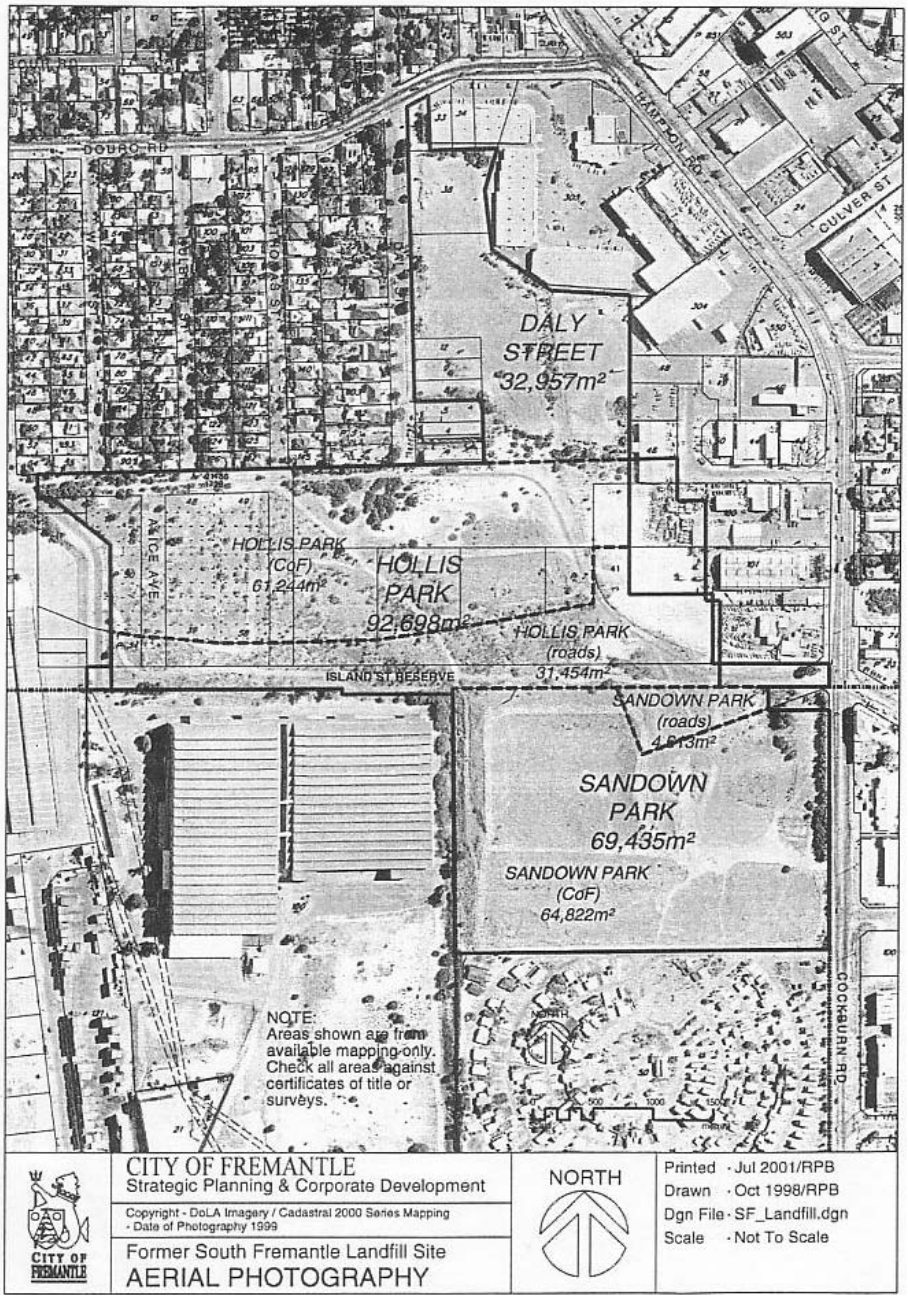
Uncertainty regarding the nature of waste in a landfill can often make management and monitoring more difficult. Contaminated sites are of great significance in Western Australia due to the dependence on groundwater resources which account for 50% of the metropolitan drinking water (Department of Environmental Protection 2002). The Contaminated Sites Bill was introduced in November 2002 to address the deficiencies in current legislation regarding the management of these sites (Department of

Environmental Health 2002). This includes clear rules for assigning responsibility for the remediation of contaminated sites.

The landfill site

The South Fremantle landfill site covers an area of approximately 19 hectares. For study purposes, it has been divided into 3 distinct areas: Sandown Park, Hollis Park and Daly Street. (Figure 1). The site is bounded by a residential area to the north and a highway and commercial development to the east. On the west side, a narrow belt of industrial land separates the site from a coastal recreation reserve. To the south, a caravan park has been built on the southeast corner of the landfill and beyond this are major industrial sites with the potential for urban development.

Figure 1: South Fremantle landfill sites outlined in a discussion paper July 2001 for community comment.



Source: City of Fremantle Council (2001)

The landfill is enclosed by Tamala limestone resting on siltstone and shale. The Sandown Park and Daly street sites were originally developed as limestone quarries before being filled (MMA 1992). The history of the site filling is outlined in Table 1. The information on depth of fill at each site was established by the PPK investigations in 1998 and OTEK in 1999 using monitoring bores. They developed boreholes across the site to determine the nature and extent of fill. No preparation was carried out for any of the sites prior to waste deposition (e.g. lining of the base of the site or leachate collection and monitoring systems) as would be required by current legislation.

Table 1: History of waste filling in 3 landfill areas in the City of Fremantle Council 2001)

Area	Dates of filling	Nature of waste	Depth of Fill	Approx. amount of waste (tones)	Comment
Hollis Park	1931-59	Domestic, sewage, waste oil	4.4m	52,000	Waste deposited between sand dunes, East-West
Daly Street	1955-74 1980-86	Domestic, industrial, fly ash, heavy metals, PCBs	8m	240,000	Dumping recommenced here when Sandown Park reached capacity
Sandown Park	1956-80	Domestic, industrial, fly ash, wool bales, skins, tires, car bodies, marine bilge oil, hydrocarbons, asbestos?, batteries?, chemical drums?	12m	600,000	Caravan Park located on SE corner of site

Closure of the sites

When dumping ceased, the waste was covered with a capping layer of uncompacted clean sand and rubble. In some areas, this layer is up to 1m thick, however, over much of Sandown and Hollis Park, the layer is absent or less than 0.5m thick. The capping layer is ideally supposed to protect the environment from the waste within the landfill by preventing infiltration of water and enabling vegetation to grow and minimize erosion. Apart from this layer, efforts to rehabilitate the site were minimal.

Use of the site

The majority of the landfill site was left vacant following closure, however in 1985, interest was expressed in developing the southern part of Sandown Park. The imminent America's Cup defense and challenge series led to a demand for low-cost holiday accommodation since there were no other facilities in the area (Hassell Planning 1985). The site was thus leased with license for development as a caravan park, the Fremantle Village and Chalet Centre. This was then developed for the start of the yacht races in 1986 with minimal further rehabilitation efforts. The initial license was for temporary residence only (according to the council).

In 1997, changes occurred in the legislation regarding caravan parks in Western Australia, which meant that a fixed proportion of caravan sites could be occupied as permanent residences. Thus permanent residences were being built on the landfill site without a real appreciation of the consequences by local authorities. This has led to a number of issues which will be discussed later. The remainder of the site was left vacant and unremediated with the exception of fences being built around hazardous areas such as sullage pits and a walkway across the site which was upgraded to a cycleway in the mid 1990s. Signs were constructed by the council advising people to stay on the path due to the uneven surface of the ground. These have recently been embellished by local residents with signs reading "TOXIC". An area of Hollis Park has been grassed and planted with trees to form a park.

Investigations carried out on the site and problems highlighted

A number of investigations have been carried out on the landfill site since dumping ceased in 1986. Various companies were commissioned to carry out studies to assess specific aspects of monitoring and management. Some of these investigations, for example groundwater monitoring and methane studies, have produced contrary results. This can perhaps be explained by changes over time as the waste decomposes and partly by the fact that the results of bore analyses cannot be extrapolated across the site due to the uncontrolled nature of filling. The main results of the studies are summarized below in relation to the specific problem being investigated (Table 2).

Table 2: Summary of gas studies on the South Fremantle landfill site from 1986 to 1996

Year	Company	Details	Findings
1986	CSIRO (Barber and Breigel, cited in PPK 1998)	Soil-methane survey of intended Caravan Park site	High concentrations of methane at shallow depths. Recommended foundations should have adequate venting
1989	CSIRO (Barber, Breigel & Power, cited in PPK 1998)	81 auger holes over Sandown Park, Hollis Park and Daly Street	High concentrations of methane found except at Hollis Park. 10% of holes>50% methane conc.
1992	Mackie Martin & Associates Pty Ltd	Soil-gas survey, 6 locations at Caravan Park	Low methane concentrations except 1 location 38.4% Groundwater contamination also identified
1994	MMA	Soil-gas survey. 6 locations at Caravan Park	Low methane concentrations except 1 location 38.4% Groundwater contamination also identified
1996	PPK	Results not released publicly	Recommendations:" soil capping with inert fill (and) a landfill gas recovery system"

Landfill gas

Landfill gas is produced by the bacterial decomposition of organic waste material within the landfill site (ATSDR). This gas consists mostly of methane and carbon dioxide with water vapor. Other gases are produced by the reactions of chemicals within waste, such as ammonia and chlorine bleach, which releases a harmful gas. Small quantities of non-methane organic compounds may also be present. Landfill gas is able to migrate through permeable material and would easily penetrate the sand capping layer over the South Fremantle landfill site. Landfill gas is able to travel beyond a landfill although the distance traveled is difficult to predict since it depends on wind speed and direction, temperature, barometric pressure and surrounding soil conditions. Travel distances of more than 50 m have been observed. No off-site landfill gas monitoring surveys have been undertaken in South Fremantle, therefore the potential for off-site migration is unknown. It may be affected by the development of the site itself or adjoining areas. Migrating landfill gas may reach buildings and homes and enter via foundation cracks, floor drain systems and other entry points. The design and maintenance of the building generally determines the amount of gas entering it and basements generally provide the easiest access for gases in the soil. This may also be a problem for caravans, particularly those with a permanent base.

Recommendations from the 1996 study suggest that significant concentrations of methane were found although actual results have not been publicly released. The biggest problem with landfill gas is its potential to form an explosive mixture when combined with air in the right proportions. The gas must collect in a confined space to reach an adequate concentration. Methane poses the greatest explosion hazard in landfill gas and is explosive between 5% and 15% by volume (termed the lower (LEL) and upper (UEL) explosive limits respectively). The problem is compounded by the fact that methane is a colourless and odourless gas (ATSDR). Gas is most likely to reach an explosive concentration when it collects in a confined space such as a manhole or basement. Within the landfill itself, methane concentrations are usually much higher than its UEL (typically 50%) so it is unlikely to explode within the landfill. Explosion is also prevented by the lack of oxygen within the waste. Landfill gas explosions are uncommon but a number of incidents have been documented in the USA. In 1994, a woman was severely burned by a methane explosion while playing soccer in a park built on an old landfill in Charlotte, North Carolina. In 1987, gas migrating from a landfill site was the suspected cause of a house exploding in Pittsburgh, Pennsylvania.

An unusual hazard posed by landfill gas is asphyxiation which only occurs when it collects in an enclosed space and reaches concentrations high enough to displace air and create an oxygen deficient environment. Carbon dioxide is the predominant constitute of landfill gas contributing to this hazard as it is denser than air and may comprise up to 60% of landfill gas. Carbon dioxide concentrations of more than 10% can cause unconsciousness and death. Utility workers entering confined spaces near landfill sites are at highest risk of asphyxiation problems.

Sulphides in landfill gas produce odours which are a common cause of complaints from nearby residents. However, no long-term health effects have been associated with low-levels of exposure occurring near landfills.

Groundwater

The area around the Perth metropolitan area is particularly susceptible to groundwater contamination due to a geological predominance of leached sand which has a high filtration rate. Chloride and ammoniacal-nitrogen are the most common contaminants.

A number of investigations into the South Fremantle landfill site have concluded that groundwater quality has been impacted by leachate from the wastes (MMA 1992, MMA 1994, PPK 1998). In fact "groundwater analyses from all monitoring bores throughout the site exceeded the ANZEC/NHMRC (1992) guidelines for the protection of freshwater aquatic ecosystems for at least one analyte" (PPK 1998).

A hydrogeological study in 1992 by MMA concluded that groundwater contamination was likely to the south west of the site. This was reinforced by the identification of groundwater contamination extending westwards in 1994 (MMA). HGM found elevated nitrate levels in groundwater samples in 1995. Dames and Moore found elevated nitrogen concentrations to the west of Sandown Park in 1998. In fact it was shown that the level of ammoniacal-nitrogen in groundwater beneath Sandown Park is 4000 times greater than the guideline limit (PPK 1998). However, this result should be balanced by the fact that elevated nitrate levels are known to be widespread in Australia's groundwater. This may be due to a natural process or from agricultural practices as well as from waste. PPK also reported in 1986 that the water table was in contact with the waste materials on the site.

The Fremantle Council has already acknowledged the need for ongoing soil and groundwater monitoring at six to twelve monthly intervals until there is no longer a potential threat to the groundwater. The cost of this has been estimated to be $25,000 to $30,000 annually.

Landfill leachate

Landfill leachate is generated when water comes into contact with putrescible wastes. Thus, rainfall, irrigation or concentrated stormwater runoff can contribute to leachate generation. The liquid wastes on the landfill, including marine bilge oils, chemicals and sullage are likely to be a major contributor in South Fremantle. Leachate may contain almost any chemicals, including high concentrations of heavy metals, dissolved solids, chloride and ammoniacal-nitrogen. It is the leachate that contaminates the groundwater. This means that the ongoing groundwater contamination cannot be halted unless the waste is removed. It is virtually impossible to remove the contaminated groundwater and therefore it remains a potential hazard for both reticulation and drinking water. Accessibility should be restricted.

Interviews

A number of interviews were carried out by telephone or in person to gain additional information about the site and clarify some of the issues. Some of these are outlined below.

Interview with Mr. Lee Bell (6 June 2003)

Mr. Lee Bell is a spokesman for the Western Australia Contaminated Sites Alliance. This is a community-based group, working to highlight the issues of contaminated sites throughout the state. Mr. Bell described the landfill as the biggest site he has ever dealt with both in terms of size and the complexity of the issues surrounding it. Estimated costs of options for remediating the site are equally enormous. Issues affecting the Caravan park were highlighted in a report produced for the park owner by PPK in 1996. This report has not been released publicly but Mr. Bell said that the investigation had identified risks of dermal contact and inhalation in excess of all known guidelines and concentrations of methane gas that were beyond acceptable levels and therefore a significant explosive risk. The results remained unacceptable even after modeling and risk assessment modification. Thus the residents were at high risk from the contaminated dust and methane. He said that both the Council and the Health Department were aware of the report. However, the writer has not been able to substantiate these claims without having access to the report itself.

These results were in contrast with the 1992 study by Mackie Martin and Associates who failed to detect significant methane concentrations in 9 out of 10 of the boreholes over the remainder of the site. Mr. Bell pointed out that the methane testing during this study was carried out in the winter when the groundwater suppressed the methane. He felt that over the seven years since the study, the methane levels are unlikely to have reduced because the gas can persist for 50 years. He felt that the groundwater contamination due to the waste is extensive and likely to be contaminating the water being pumped from bores in residential areas as well as the ocean.

The current rehabilitation effort of a thin capping layer of sand over the waste served only as a means of reducing physical contact with the waste and would not prevent gas escaping. Mr. Bell acknowledged that management of the site would be a very difficult and potentially extremely expensive problem. A capping layer of clay might contain the gas but could potentially lead to a build-up of methane beneath it. It would not solve the problems of leachate and groundwater contamination.

He believed that the idea of a gas recovery system would be feasible despite the time lag since closure of the site as such high concentrations of methane are still present. However, removal of the waste was considered impossible due to the presence of discrete chemical pits and large amounts of fly ash containing heavy metals such as mercury and barium. Excavations would create large amounts of contaminated dust, necessitating the evacuation of local residents within a 5km radius of the site. This would be prohibitively expensive. One option would be to excavate only the areas known to have the highest level of contamination according to local knowledge and site maps, however, a fair amount of undocumented dumping also occurred.

Mr. Bell was of the opinion that the council could not afford the clean up, which was the reason developers were being invited to develop the land and pay for the remediation as well. He said that this has been shown to result in poorer standards of remediation due to cost-cutting measures. These savings would rebound with expensive problems in the future. He felt that the idea of building residential areas on part of the landfill site was "asking for a disaster" as already exemplified in the caravan park. In the USA and the UK, people are not allowed to live permanently on former landfills, "for good reason".

Interview with caravan park resident (May 2003)

A telephone interview was carried out with one of the residents of the caravan park. She outlined some of the history of the development of the caravan park, described her experience of living on the site and the community which has developed there and explained some of the concerns which are currently troubling many of the long-term residents.

The caravan park is situated in the south east corner of the original landfill site and consists of chalets and sites for tents and caravans, catering mainly for tourists (50%), and mobile homes occupied by residents who have made the park their permanent home. Some have lived there since the park was first established for the America's Cup 17 years ago. Most were aware of the nature of the site but presumed that it was safe or had been remediated since the council permitted the development. The residents have no tenancy agreement but pay site fees to the owner of the park. This makes their future rather uncertain and they have few rights. Many are afraid that they may be evicted if they take a stand or speak to the media about environmental issues affecting the site. Apparently no one has actually been evicted to date.

The Department of Health recently informed the owner of the park that no more homes could be moved on to the site while further investigations were being undertaken, possibly to review the results of tests he had commissioned. A few years ago, the owner proposed the building of an office and tennis courts on the site but this was refused due to the potential for gas build up underneath.

The resident described her experiences in her garden. She discovered that the waste in the ground was so close to the surface that plants with taproots "burned" and died as soon as their roots reached the waste. Residents were not allowed to eat vegetables grown on the site. She described a time a few years ago when the gas company fitted a gas supply to the homes and shallow holes dug in the ground exposed offensive-smelling waste. People had car bodies and hospital syringes exposed in their front gardens. The residents are aware that they are "the only people in Western Australia living on a landfill site". She described the development of the so-called Ecovillage on the land neighboring the site, with a constant stream of trucks carrying clean fill past her door from dawn to dusk every day (at an estimated cost of $8 million).

Interview with Ms. Jill Gaynor, City of Fremantle - Land Development Officer (June 2003)

Ms. Jill Gaynor outlined a number of issues which have made assessment of the site for remediation and management more difficult. These include the history of the site and its surroundings which have been dominated by heavy industry for many years. Car manufacturing plants, a timber mill, whitewash manufacturing and runoff from the roads may have contributed to the contamination with hydrocarbons and even arsenic. Thus it is unlikely that the landfill is the sole cause of the problem, although this is impossible to prove. She acknowledged that the groundwater is contaminated, but claimed that it was only being used for irrigation.

Designation of responsibility for the management of the landfill site is important for the Council because this has significant liability implications for paying for the remediation of the site in the light of the recent Contaminated Sites Bill. The Council felt that they were fulfilling the obligations imposed by the State to provide waste management options for household waste. This was done in accordance

with legislation at the time. Therefore they felt that some responsibility for funding the clean up should be borne by the State.

Other developments in the area have implications for the management of the site. An "Ecovillage" is currently under construction on an old industrial site between the southern part of Sandown Park and the coast. This land is contaminated with heavy metals from the industry but development will consist of expensive, permanent homes. The coastal situation of this land makes development attractive but the implications of the contamination and potential problems with landfill gas or contaminated groundwater from the neighboring landfill are unclear.

Regarding remediation of the landfill site, balancing the desires of the local residents with the need to develop the area to fund the remediation is a difficult task. Different options are being considered for each of four areas of the site. Hollis Park has the potential for development of residential housing as the fill is considered stable. This has the advantage of earning revenue for further remediation work and developing a community with the "Ecovillage," however local residents are not keen on the development of more housing. Another option would be to remove and incinerate the waste at a new site in nearby Kwinana and replace it with clean fill. However, the cost of this is likely to be enormous and would create a significant problem with dust and noise. An option of developing a school and playing fields on Sandown Park may be feasible if the methane is managed adequately. A golf course is another proposition. The cheapest option would be to fence off the site and leave it which would fulfill the Council's obligation of minimizing the risk to the population but would not solve the problems of the groundwater contamination. It would also be a waste of potentially attractive land. The main underlying problem is that of funding which, at present, is inadequate for any of the above options.

Telephone interview with staff member at the Toxicology Department of The Department of Health (May 2003)

In a brief telephone interview, the staff member said that she was not at liberty to discuss the current information relating to the landfill site. Studies are currently being undertaken to investigate the long-term risks of living on a landfill site, particularly relating to methane and toxic products. The caravan park seems to be the main target of the investigation and energy is being directed toward finding potential solutions to the problem. She emphasized that the aim of the Health Department was not to get the residents "kicked out" of the caravan park but to examine alternative solutions to the problem.

Media reports

The issues surrounding the South Fremantle landfill site, and particularly the caravan pPark, received a significant amount of media attention in May and June of last year (Amalfi 2003). This included articles in the West Australian newspaper, the Fremantle Herald and the Fremantle community web site. Reasons for this sudden interest include the recent Contaminated Sites Bill and the current debate between the Council and local residents regarding the future of the landfill site.

Two articles graphically described the plight of residents at the caravan park, outlining the potential risks of methane gas explosion which, although unlikely, could be catastrophic. Mr. Sanders, the manager of the Caravan Park accused the Health and Environmental Protection Departments of "trying to shut him down over bogus concerns based on a lack of evidence and alarmist activists" (Amalfi 2003a). He said "there are no health issues here. There is no methane risk". I attempted to contact Mr. Sanders, but he was not available for comment. In the same article, Mr. Devine, the acting director of environmental health in WA outlined concerns that the new Ecovillage development could present "methane problems if the project acted as a gas trap on the western edge of Mr. Sanders' site" with "the risk of methane moving laterally from the tip site into the multi-million-dollar Ecovillage site". The ecovillage project manager, Mr Mike Hulme was reported as saying that he "was not concerned" about these issues.

Ms. Jill Gaynor expressed frustration to me that the articles had been published without contacting the council to give them a chance to act or respond to the negative and accusing comments about their actions. Papers produced by the Council have emphasized their openness to receive input from the community regarding their opinions on the future of the site. A community discussion paper produced and circulated by the Council last year explains the background and current issues surrounding the site and invites the participation of local residents in the decision making process via a questionnaire and workshops (City of Fremantle 2001).

Comparable situations to draw from

The issues at the South Fremantle landfill site, although complex, are not entirely unique in many ways. Similar issues are involved in managing landfill sites around the world, often on a larger scale. The following cases from beyond Australia outline similar problems and management issues. The management options used or being considered are explored with their potential transferability to the situation in South Fremantle.

Case 1 - Wright-Patterson Air Force Base (ATSDR)

The Wright-Patterson Air Force base is located near Dayton, Ohio, USA. Two landfill sites were operated at the base from the late 1940s until the early 1970s and then closed by covering the waste with a soil layer varying from about 30cm to 4m deep. No other control measures were used and a military housing area was built beside the landfill which was used as a recreation and playground area. The following concerns were raised in the 1980s:

- Waste settling led to subsidence and the demolition of one of the housing units
- Concern about exposure to migrating landfill gas
- Concern about direct contact with contaminants
- Concern about potential explosion hazards from the methane

Studies were carried out by the US Air Force under the guidance of the Ohio Environmental Protection Agency (OEPA) from 1985 onwards, with additional input from ATSDR (Agency for Toxic Substances and Disease Registry) from 1990. Soil gas, ambient air and indoor air in nearby homes were sampled. Despite a number of potential inaccuracies due to the sampling techniques, ATSDR concluded in 1990 that the landfill posed an explosion hazard for the houses built beside it. This case has many similarities with the situation at South Fremantle, particularly the caravan park where residents are living on a potentially hazardous site. In the Wright-Patterson case, ATSDR recommended the evacuation of homes where there was an explosion hazard until the gas emissions were controlled. The US Air Force complied with this and designed and installed a number of landfill gas collection systems over a two year period. This involved the installation of an impermeable geomembrane and a two-foot soil cover. A series of active gas collection wells were constructed and the gas burnt in flares. The collection system was regularly maintained and samples taken to ensure its ongoing optimal performance. Efforts were made to involve the community at all stages of the developments and address their concerns.

Case 2 - Peterson/Puritan Superfund site in Rhode Island

The issue of groundwater contamination was encountered at the Peterson/Puritan Superfund site in Rhode Island (US Environmental Protection Agency 2000). The 980-acre site, including both industrial and landfill areas, was found to be a major source of pollution of the Blackstone River and of contamination of the water supplies of the residents of two nearby towns. The groundwater contamination resulted from a combination of the products of manufacturing industry, a rail car spill in 1974 and the hazardous waste in the landfill site.

The problem was addressed by cooperation between the Environmental Protection Agency, the Rhode Island Department of Environmental Management, the parties responsible for the pollution and the local community. Remedies included:

- Establishment of an alternative water supply for the residents from a neighboring town
- Excavation of contaminated soil
- Installation of a groundwater extraction and treatment system
- Development of systems to extract soil vapor to remove organic chemicals
- Treatment of arsenic in groundwater by oxidation
- Continued monitoring of the groundwater, soil and air

The treatment systems were set up over two years and will operate for 4 to 12 years to complete the clean up. Businesses on the site continued to function during the cleanup, providing ongoing income to the 800 local employees which was of obvious benefit to the community. The cleanup also generated jobs on the site, protected the environment and local residents from the contaminants, provided recreational space and led to a significant potential increase in residential property values. However, the cost of the cleanup is not specifically mentioned in the case study, but it appears to have been paid for by a combination of the parties involved.

Groundwater contamination is an issue at the South Fremantle site but since this water was not thought to contribute to a municipal supply, it seems that the cost of addressing the problem was not justified to those likely to be paying for it.

Case 3 - The Normandy Landfill, Beirut, Lebanon

This is an example of an issue which has similarities to the South Fremantle site, but on a much larger and more complex scale. The Normandy landfill was created by the dumping of municipal waste in the Normandy Bay along the Mediterranean coast during the Lebanese civil unrest (1975-1990). It is located literally in the centre of the business, historic, touristic and cultural centre of Beirut and covers an area of about 360,000m^2, extending 600m beyond the original shoreline (Sadek & El-Fadel 2000).

The Lebanese Council for Development and Reconstruction has commissioned a private real estate company (SOLIDERE) to manage and remediate the site. This has become one of the most controversial projects in the city centre. Extensive investigations have been carried out at the site which is thought to contain all types of waste from medical and industrial waste to construction rubble and potentially even mines. Management options included the development of an exclusive business district with luxury tourist resorts and houses which would provide revenue to fund the high costs of rehabilitation. However, this met with opposition since it would profoundly change the demographics and traditions of a historic area at the heart of the city. On the other hand, leaving such an environmental hazard in the middle of the city was not an option.

A similar dilemma is being faced in Fremantle, in that site development plans have met with strong opposition despite developmental funds being required to pay for site remediation.

Case 4 - The Jakusevac site in Zagreb, Croatia

An example of the huge economic costs involved in remediating a landfill site was demonstrated in Zagreb, Croatia. The Jakusevac site, located within the built-up area of Zagreb, covers an area of 80 hectares and is the largest uncontrolled landfill in Europe. Contamination of groundwater threatens the water supply of one million inhabitants of the nearby city (EBRD 1997, 1998). The rehabilitation project is being supported by a loan from the European Bank for Reconstruction and Development (EBRD) and is estimated to cost US$98 million. This loan is extremely significant for the economic transition of Croatia. Obviously, the remediation of the 19 hectare site in South Fremantle will not incur such enormous costs but it can be appreciated that such projects have significant financial implications.

Impact of the South Fremantle landfill site

Budget

The economic impact of the landfill site can be divided up into a number of areas:

The cost of remediating the site

Cost estimates for the different development options vary significantly and have increased dramatically over the years of investigations.

- Fencing the site to prevent access - $60,000
- Capping and partial development - $15 million
- Removal of waste and replacement with clean fill - $70 million.
- An active landfill gas control system - $1 million to set up plus $120,000 annual operating costs (PPK 1998 estimate)
- Passive venting $100,000 plus ongoing costs

The first 2 options may also require ongoing groundwater monitoring at $25,000 annually. It is clear that remedial work completed years after closure cost substantially more than work done at the time. These expenses will have a significant impact on the budget available for other needs within the city. The cost of site investigations is also significant (estimated $250,000 for a consultative environmental review, PPK 1996).

Land value

The large area of vacant land means a loss of potential income for the Council. Proximity to the site is also likely to have lowered property value in the surrounding area.

Liability

This area currently remains somewhat unclear since the implications of the Contaminated Sites Bill have not been fully worked through. However, there is a significant risk that the Council may be held liable for the adverse impacts of the site (City of Fremantle 2001).

Health

A number of studies have attempted to identify long-term health problems such as cancer, low birth weight or birth defects associated with residence near a hazardous waste landfill site (Goldberg et al 1995, 1999; Dolk et al 1998). However, the results have been largely inconclusive, mainly due to difficulties in quantifying exposure and potential confounding factors such as socioeconomic status, lifestyle choices and the proximity of landfills to other industrial sites. No studies have been completed to assess health impacts in the South Fremantle area. However, the potential risk of methane explosion at the caravan park is likely to be the most serious health threat.

Morale

Communication regarding the site has generally been positive between the community and the council. However, uncertainty about the future has created distrust between the caravan park manager, the council and the park residents. Remediation of the site, regardless of the option chosen, is likely to impact the local community, with problems of noise, dust, odor and disruption caused by heavy vehicle traffic.

Management Issues

The following steps need to be taken initially in managing the site:

- Elect a group of individuals within the council to oversee the investigations and evaluate management options.
- Involve other stakeholders such as local residents, landholders and government agencies to provide input into the decision-making process.
- Keep the wider community informed about progress and invite comment.
- Establish available sources of funding. These may include the state government, commonwealth funding or private developers. The council's municipal fund is grossly inadequate for the potential costs involved.
- Different plans may need to be considered for each area of the site due to variation in the nature and stability of the fill.
- Dialogue with regulatory authorities such as WA Health Department, Water and Rivers Commission, DEP etc.

The following management plan may be feasible for the site:

- The use of a geomembrane to act as a gas collection blanket
- Covering the membrane with an impermeable clay liner
- Constructing a landfill gas collection system (with potential for energy generation)
- Controlling and treating the gas using a combustion method
- Ongoing monitoring of the gas collection system
- Ongoing groundwater monitoring and restrictions to ensure the water is not accessible for use.

A geomembrane consists of a non-woven needle punched geofabric, which contains the gas and can be used to create preferred migration pathways (Geofabrics 2001). It is laid using a spreader bar and can be installed very rapidly. The gas then vents through collection wells made of perforated plastic, installed vertically throughout the landfill to depths of 50 to 90% of the waste thickness. A passive landfill gas collection system uses existing variations in landfill pressure and gas concentrations to vent the gas into the collecting system. Combustion would be the most feasible option for treating the gas given the likely volumes collected from the site (ATSDR).

A geomembrane system has been used effectively in the rehabilitation of a number of landfill sites in Australia as illustrated below (Geofabrics 2001).

- The Reid Street landfill site is located 11 km west of Melbourne and was heavily contaminated by ammunitions testing over a period of 80 years. Remediation of the site was carried out in 2000-2001 using a gas collection blanket made of non-woven needle punched geofabric called bidim®A44R. This acted as a gas transmissivity path to aid collection in a perimeter gas

collection trench. A geosynthetic clay liner called Bentofix®X2000 was then placed over the geofabric to act as an impermeable barrier.

- At King Park, a former landfill site north of Newcastle, a Bentofix®X750 geosynthetic clay liner was used successfully to cap the site so that sports facilities could be developed and landfill gas emissions could be managed. Passive gas collection trenches were built around the perimeter and across the landfill. The material was found to be relatively cheap and the ease of installation meant that specialist labor was not required which further minimized costs.

A similar capping system would definitely be a feasible option for areas of the South Fremantle landfill site as it is relatively inexpensive, easy to install and addresses the problem of landfill gas emission. One cost estimate for geomembrane installation in the USA was US$3.90 per square yard for the membrane and US$5.67 per square yd for the clay capping layer (KDHE). Issues which may determine the particular geomembrane used include the brittleness of the membrane, differential response to settlement, gas migration through the membrane and the potential for rats eating it (PGI Technology Program 1999). Capping the site may improve groundwater quality by preventing precipitation from reaching the waste and so reducing leachate generation (OTEK 2000).

The caravan park poses a more difficult management problem since it would be impossible to cap the waste effectively and manage the gas without evacuating the residents and moving their homes. A geomembrane may be effective here, but an active gas collection system may be required, given the potentially higher concentrations of methane and the catastrophic impact of an explosion. This would include horizontal as well as vertical collection wells with valves to regulate gas flow and vacuums or pumps to move gas out of the landfill. The option of using the biogas for some purpose has not really been explored at the site due to uncertainty regarding likely quantities of gas. However, this has been carried out by other municipal providers elsewhere in Australia. The residents would require temporary housing elsewhere while the work was being done. A less satisfactory but much cheaper approach would be the installation of methane gas alarms in areas where the gas could potentially collect. However, this does nothing to address the underlying problem.

It should be noted that the management of newer landfills is governed by much more stringent controls designed to prevent pollution and avoid the development of problems such as those outlined in this report. This is associated with significantly increased costs in site preparation, general operation and monitoring but results in a dramatic saving in long-term rehabilitation costs. I would not recommend residential development on any area of the South Fremantle site, considering the potential for decomposition and significant settlement of the waste even if the methane were to be controlled. Rehabilitation of landfill sites in other parts of the world has not included construction of housing.

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