This paper is based on the findings of a regional solid waste disposal study performed for the Roanoke (Virginia) Valley Regional Solid Waste Management Board. The project objective was to provide the Board with the best waste disposal direction for the future. The study evaluated and compared the technical and economic feasibility of various waste disposal alternatives for the region including landfilling, shredding, baling, composting and resource recovery. The consultant’s recommendations are included.

INTRODUCTION

The Roanoke, Virginia Valley Regional Solid Waste Management Board, comprised of representatives from the City of Roanoke, Roanoke County and the Town of Vinton, was faced with the planned completion of the Regional landfill. Final planned elevations were three to four years away when the Board instigated a solid waste management study to consider the various methods for disposal of solid waste generated in the service area.

PURPOSE AND OBJECTIVES

The purpose of the Roanoke Valley Regional Solid Waste Study was to evaluate alternative methods of solid waste disposal for the region, taking into consideration both technical and economic factors. Based on the study findings, a future course for solid waste disposal was recommended.

Specific objectives of the Solid Waste Study included:
1. Minimize adverse environmental impacts from solid waste.
2. Comply with Virginia regulatory requirements.
3. Provide direction for solid waste management in a manner which will permit long-range flexibility and utilization of developing technology.
4. Consider the practical recovery of secondary materials or energy.
5. Select and implement a solid waste system which is economically viable.
6. Review institutional relationships and responsibilities of the Board to carry out the recommended alternative.
7. Encourage continued intra-regional cooperation.
8. Make recommendations to the Board for adoption of a waste management strategy and procedures for plan implementation.

EXISTING SOLID WASTE SYSTEM

The existing solid waste management system in the Roanoke Region is a combination of public and private collection, disposal and resource recovery. The major elements of the system include:
1. Private and public haulers and collectors of solid waste.
2. Regional landfill operated by the Board for
disposal of most of the waste generated in the Region.
3. A private landfill receiving mostly demolition and non-putrescible wastes.
4. A privately owned source separation plant.
The Regional landfill is a 245 acre (0.99 sq km) site nestled in the rolling hills of an old farm in the southeast portion of Roanoke County. The landfill is operated by the area method, with the hollows on the site being dug out rather than trenched. The model operation has been ongoing since 1976 with no indications of environmental pollution. The current landfill operation cost $5/ton ($5.51/t) including replacement reserve.

The Regional Solid Waste Board has been keeping weight records of refuse landfilled at the Regional landfill since September, 1976. Daily refuse tonnages averaged 350 tons/day (3.18 t/day) over the last 5 years. Projected refuse tonnages are expected to peak in the mid 1980's around 390 tons/day (354 t/day) and stabilize around 380 tons/day (345 t/day) in the later 1990's.

DISPOSAL ALTERNATIVE DISCUSSION

An investigation and evaluation of seven basic alternatives for solid waste disposal for the Roanoke Valley Region was conducted. Consideration was also given to the inclusion of a transfer station in the solid waste management plan for the region. A discussion of each of the alternatives follows.

LANDFILLING

The landfill disposal process possesses several advantages and disadvantages for the Roanoke Region as follows:

ADVANTAGES
1. Lower capital investment and operating costs than required by other processes.
2. Land may be purchased or leased and reclaimed for other uses.
3. Majority of equipment required is virtually standard equipment in the construction industry.
4. No highly technical personnel are required.

DISADVANTAGES
1. Availability of land.
2. Availability of cover material.
3. Potential public opposition to the process due to bad reputation caused by poor operation of other landfills in the past.
4. Leachate collection and treatment facilities may be necessary to minimize groundwater pollution potential.

One sanitary landfill option considered was the expansion and continuation of the present Regional landfill. Conceptual plans to continue the existing landfill operation were formulated. By raising the top of the landfill to the maximum possible height, the top elevation would be increased approximately 90 ft (27 m). Assuming 3:1 side slopes, it was estimated the existing operation could continue for 10 additional years. The estimate was based on a 3:1 refuse to cover ratio and a landfill density of 1,000 lb/cu yd (593 kg/m³).

The primary economic advantage to be gained by continuing the existing landfill operation was the capital cost savings. Since the land and equipment were already owned, no capital investment was required to continue the existing operation.

The current operating costs for the Regional landfill are approximately $5/ton ($5.51/t) based on the following cost breakdown:

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<tr>
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<td><strong>TOTAL</strong></td>
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</table>

A secondary sanitary landfill option considered was the acquisition of a new landfill site. In addition to the existing landfill three potential future sites were investigated at the Board's request. All three sites were found to be deficient as potential landfill sites for one or more of the following reasons:

1. Lack of available on-site cover material to provide the daily, intermediate and final cover required by law.
2. High water table.
3. Portions of the property located in flood plains.
4. Limited or poor site access.
5. Poor soils and hydrogeological characteristics.
6. Railroad crossing on access roads.
7. Too small a site to justify development.
8. Tract consisting of numerous parcels which must all be coordinated in the property purchase.
SHREDDING

Solid waste shredders have historically been plagued by excessive down-time, periodic explosions and high operating costs. For example, in early 1981 the Palomar Transfer Station shredder, a well-operated facility in San Diego, California, experienced an explosion that blew out three walls of the station due to a can of varnish passing into the shredder [1]. Other shredder-related explosions which have led to costly maintenance and down time have been reported at Brevard County, Florida; New Castle County, Delaware; Lane County, Oregon; Chemung County, New York; and Toronto, Canada [2]. Therefore, the disposal option of shredding followed by landfill (i.e., shred-fill) was eliminated as a viable alternative early in the study process.

BALING

Baling was recognized as having two distinct advantages for the Roanoke Region:

1. Increased density which lengthens the life of a landfill. A baler could increase in-place refuse density from 1,000 lb/cu yd (593 kg/m³) estimated at the landfill to 1,500 pcy (890 kg/m³) or more in the bales.

2. Better operating conditions because the need for all-weather operation is mitigated by the baler shelter. Baled refuse could be “stockpiled” in a storage area until weather conditions improve to permit easier placement at the working face of the fill.

Due to the successful installation and operation of a number of balefills in the United States such as the 1000 ton/day (907,200 kg/day) installation at The Hackensack Meadowlands Development Commission in North Arlington, New Jersey, the 60 ton/hr (54,432 kg/hr) Cobb County, Georgia facility, as well as others at San Diego, California, St. Paul, Minnesota and Chadron, Nebraska, baling was considered a relatively low-risk process with a possible application for the Roanoke Region.

The cost of high-density baling versus sanitary landfilling was difficult to compare because of the sensitivity imposed by operation parameters. A baling facility generates less expense for equipment maintenance; however, the capital cost for equipment is higher for a baling facility than for a landfill. Equipment was compared on the basis of compactors, pans, and bulldozers versus a baler and the tractor/trailers with either a forklift or specially equipped front-end loader for implantation.

For the Roanoke region, the total cost of operation of a baling facility with conversion of the existing landfill to a balefill is estimated to be $7.85/ton ($8.65/t). This is composed of capital amortization and operating costs for the bale operation of $5.89/ton ($6.49/t) plus $1.96/ton ($2.16/t) for balefill operating costs.

These costs were based on a 12 year life with a capital amortization rate of 10 percent. The costs were estimated to include two balers, two tractors, six trailers, a rubber tired front end loader and the required building and utilities. Baler operating costs included two shifts of ten persons each.

While the estimated cost of $7.85/ton ($8.65/t) is higher than the current $5/ton ($5.51/t) operating cost of the Regional landfill, the estimated increase in refuse density will achieve an effective increase of one-third in the air space available for filling (1500 lb/cu yd (890 kg/m³) vs 1000 lb/cu yd (593 kg/m³)). This translates to an additional four years of operation at the present Regional landfill with a vertical expansion. If the landfill operation expands horizontally onto land already owned by the Regional Board, the balefill operation could provide as much as nine additional years over a conventional landfill operation of the same site.

Resource Recovery/Steam

Resource recovery can take several forms. This study evaluated the concept of refuse incineration with steam production using mass-burning and modular units. The steam generated is a marketable product which may be used in a number of industrial applications when conditions of supply, demand and quality provide a favorable match.

A primary technical consideration is the relationship of the heat recovery incinerator to the buyer market. While the problems of generating steam from refuse at low pressures have for the most part been resolved, a major challenge remaining in the Roanoke Region was matching the performance of the heat recovery plant to the energy demand characteristics of the steam purchaser(s).

The combustible waste available to the Region of between 54 tons/day (48,989 kg/day) and 70 tons/day (63,504 kg/day) could generate an average of 7.5 tons/hr (6,804 kg/hr) of saturated steam. This quantity would vary throughout the year with significant daily and weekly variations being caused by holidays, inclement weather, etc.
Three potential markets in the Region for energy from solid waste had previously been identified: Norfolk and Western Railroad Company (N&W), Roanoke Industrial Center and the Veterans Administration (VA) Hospital.

The Norfolk and Western Railroad Company currently has a manufacturing and maintenance yard in the City of Roanoke which utilized 30 tons/hr (27,216 kg/hr) to 90 tons/hr (81,684 kg/hr) of superheated steam [475 F, 170 psig (12 kg/cm²)] for process operations. N&W presently has an abundance of cheap energy by virtue of the fact that they own nearby coal mines that can supply their coal needs at a price of $36/ton ($40/t). The use of refuse-derived fuel (RDF) could be considered at this facility. The mixing of RDF with coal could be done as the bunkers are filled. At a coal to RDF weight ratio of 80:20, this plant could not use all the available waste. The cost for preparation, storing and mixing would not be competitive with the cost of the primary fuel at N&W. Only if the cost of coal rose to more than double its present price would RDF be economically competitive.

The Roanoke Industrial Center houses the Fred Whitaker Co., an industrial dyeing facility. Whitaker Company presently produces saturated steam [325 F, 125 psig (9 kg/cm²)] fired package boilers. The steam is used primarily in the dyeing process to set the dye. The demand is lower during the winter which is the slow period for this industry. The steam demand is subject to large swings over short periods, which would be difficult to meet with a trash-burning steam generator. This steam plant did not lend itself to firing of solid waste either as a refuse derived fuel or in a mass burning mode without major renovations. In addition, this market was too uncertain to present a reliable long term solid waste disposal alternative due to seasonal variations.

The Veterans Administration Hospital is located in Salem at the border with Roanoke. The boiler house is equipped with three dual fuel (gas and oil) boilers. The furnaces are fired with natural gas and can use fuel oil as a standby fuel. The units are located on the grounds and are a part of the hospital complex.

The steam is used for heating and for sterilization of equipment. The low pressure steam at 375 F, 130 psig (9 kg/cm²) is saturated and is transmitted over relatively short distances. The steam demand varies greatly by the season due to its primary use to heat the buildings. The maximum demand in the winter could not take advantage of all the available solid waste in the region. The average summer demand could use only one tenth of the available waste. In addition, the VA Hospital had strong reservations about allowing solid waste (trash and garbage) near the hospital.

Besides judging the three potential steam markets as being unacceptable, the economics of refuse incineration were considered. Cost estimates were prepared for a 400 ton/day (363 t/day) mass burning facility and for a 100 ton/day (91 t/day) modular incinerator. The gross cost per ton for a 400 ton/day (363 t/day) facility was estimated as $16.00. The gross cost per ton for a 100 ton/day (91 t/day) modular unit was estimated as $25.00. These costs did not include a credit for a steam sale.

The mass burning unit could effectively handle the Region’s waste load. A single modular unit, which might be more suitable for supplying steam to small industry in the Region would still leave 200 to 300 tons/day (182 to 272 t/day) of refuse to be disposed. This would require other disposal facilities or multiple modular units.

In addition, both mass burning and modular incinerator resource recovery facilities have a checkered history. RDF facilities likewise have had only limited success.

Mass burning facilities are the oldest form of resource recovery and the most notable units in operation are those in Harrisburg, Pennsylvania (1970) and Saugas, Massachusetts (1975). Some mass burning operations have had periods of extensive shutdown, such as was experienced in Nashville, Tennessee and Harrisburg, Pennsylvania and other mass burning locations. Reasons for shutdown generally were the result of noncompliance with air pollution regulations. Other reasons included requirements and changes in materials handling process.

Modular incinerators do not have the extensive municipal waste processing history which mass burners have. The down time, maintenance requirements and failure rate in operations of modular incinerators have been greater than anticipated; however, the Consumat incinerator in the City of Salem, Virginia, is often pointed to as one of the more successful incinerator operations.

Refuse derived fuel operations generally have not been successful either. Monroe County, New York and Bridgeport, Connecticut, are among the RDF facilities which are either inoperative or functioning well below design capacity. Hempstead,
Long Island also has been a failure to date. While new plants are under construction, the applicability of RDF processing has not been proven. For these economic and operational reasons, resource recovery was not considered as an optional solution for the Roanoke Region.

COMPOSTING

Solid waste composting has been practiced with solid waste alone, but more often in conjunction with sewage sludge such as at Johnson City, Tennessee or with sewage sludge alone such as at Beltsville, Maryland. One historical difficulty with either type of composting is the high cost and lack of any appreciable market for the compost. Composting of solid waste requires a presizing operation (shredding), followed by removal of metal and the glass fraction.

One method of composting is known as the "windrow" concept, where compost is placed on a pad and periodically turned to allow aeration of the material. During the turning operation, odor is evolved and an environmental aesthetics question surrounds this type of operation. This process was used at Johnson City, Tennessee during 1967 to 1969 during which 30,000 tons (27.2 million kg) of refuse and sewage sludge were co-composted.

A separate approach is used with sewage sludge and is known as the "static pile" technique. With the static pile, no turning of the windrow is physically performed, rather negative draft blowers are used to draw air through the pile into a perforated piping system. Air drawn through the piles can be discharged through cured compost or activated carbon for odor adsorption if the cured compost adsorption is sufficient. The static pile technique has been used at the Beltsville, Maryland facility for sewage sludge.

Although between 60 percent and 75 percent of the solid waste is paper, food waste, leaves, or other cellulosic materials, the amount of material which undergoes composting is only between 20 percent and 30 percent. Finished compost of un-separated municipal refuse maintains the general appearance of shredded solid waste. Coated paper, plastics, and other light fraction materials are part of the mixture which do not undergo decomposition. As such, the final product must be screened and separated to produce a compost which is attractive for land or soil conditioner.

The Lehigh County Authority composting facility in Allentown, Pennsylvania, which was designed to handle 400 tons/day (363 t/day) of solid waste, had production costs including capital amortization of $16/ton ($17.63/t). Under the most optimum conditions, the cost for waste processing could have been reduced to $12/ton ($13.22/t) if the compost was sold at $40/ton ($44.60/t).

In general, composting is not a viable alternative for waste disposal. Because of the high costs associated with composting, it was not considered any further as an option for the Roanoke Region.

RESOURCE RECOVERY BY PRIVATE ENTERPRISE

A private firm in Roanoke operates a resource recovery system capable of recovering between 50 and 75 tons (45 and 68 t) of waste paper per day. The system consists of a floor-dump tipping area, with a rubber-tired front end loader feeding the charge conveyor to the trommel. Wastes are separated into the paper recovery fraction and the rejected fraction. Operation of the system appears promising, but the amount of waste which could be processed economically was undefined. The firm was interested in establishing a dedicated part of the market for resource recovery, but was unable to determine the tipping fee needed to assure financial viability. The firm's estimated break-even cost was $8/ton ($8.81/t), which is greater than the Regional landfill cost.

TRANSFER STATION

It is recognized that refuse transfer is not a waste disposal process. On the other hand, it is a waste handling process which can affect overall solid waste management processes and costs, and, therefore, was considered in the planning process for the Roanoke Region.

Most transfer operations simply compact the wastes from several collection compactor trucks into transfer trailers (approximately three compactor truck loads per transfer trailer) in order to reduce refuse transport costs, however, resource recovery operations can also be performed to extract marketable materials or bulky white goods. The major unit processes involved in a transfer station operation are compacting and transport, while key design parameters are processing rate and hours of operation.
**TABLE 1 ALTERNATIVE COST ANALYSIS LANDFILL VS BALEFILL**

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<td>Estimated Waste Tonnage</td>
<td>Cost Per Ton (Inflated 10 percent)</td>
<td>Annual Cost ($1,000) X 2</td>
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<td>Landfill Development Cost ($/Ton)</td>
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* Based on 1981 costs inflated at 10 percent per annum and amortized over 15 years (CRF = 0.13447).

**LAND:**
- 250 new acres purchased @ $4,000 per acre = $1,000,000

**ENGINEERING: 200,000

**CONSTRUCTION:** (90% of site usable) (0.90) (250) ($66,500 per acre) = 15,000,000

**TOTAL:** LAND + ENGINEERING + CONSTRUCTION = $16,200,000

**Balers operating costs plus balefill operating cost inflated @ 10% per annum

**Balefill Ammortization as above, Ammortized over 22 years (CRF = 0.11401)
Utilization of a transfer station assumes that more refuse can be placed into a larger vehicle, thereby reducing the number of trips to the disposal or resource recovery facility. As haul distance increases the marginal per ton cost decreases and transfer stations become more cost effective. Transfer station technology is fairly simple. Many reliable transfer stations of varying sizes are on-line which have been operating for years.

One additional influence which would make utilization of a transfer station attractive is low technology and selective materials separation as part of the transfer operation. At a transfer station, materials, including wood, cardboard, and newsprint could be hand separated, thereby reducing the weight of material requiring final disposal. In such an operation, the waste stream could be reduced by as much as 10-25 percent.

For the Roanoke Region, if a transfer station was constructed to handle 200 tons/day (182 t/day) of refuse, the expected recycle quantity would be approximately 50 tons/day (45 t/day). Based upon the total waste generated in the Region, this is a reduction of approximately 15 percent. Capital costs of a transfer station for 200 tons/day (182 t/day) capacity would include land acquisition, design and engineering, construction, compaction equipment, tractors/trailers, and other vehicular equipment for pushing waste. A typical capital cost of between $450,000 and $600,000 was expected at this facility size.

Construction and use of a transfer station in the Roanoke Region was not justifiable on the basis of haul distance and cost savings. The capital and operating costs associated with the implementation of a transfer station would essentially be an add-on to the Regional disposal cost. Amortizing an assumed capital cost of $550,000 over 20 years at 10 percent yields a capital cost of $1.04/ton ($1.15/t). When the operating costs are added into the capital amortization, the transfer station costs of approximately $5/ton ($5.51/t) results. This cost is before disposal of the 200 tons/day (182 t/day) of the residual refuse. Adding current disposal costs of $5/ton ($5.51/t) to the transfer station cost gives a total disposal cost estimate of $10/ton ($11/t).

In evaluating items to be separated at the transfer station, wood was included. Wood is delivered from commercial and industrial establishments as packing material, pallets, from demolition and construction sources, as well as from some household contributions. Wood is not typically included in resource recovery, but a market is evolving for hogged wood as a fuel. Presently, no markets are specifically identified in the Roanoke Region, although there are several markets in North Carolina and Tennessee at existing furniture manufacturing facilities.

RECOMMENDATION

Based on the technical, environmental and economic analyses of the disposal alternatives considered, it was recommended the Roanoke Regional Board continue, for the immediate future, to landfill, and develop plans to expand the existing landfill site. In addition, the Board should begin planning to construct and operate a solid waste baler and balefill. It was realized that to convert the conventional landfill to a balefill would require a substantial capital investment. During the initial years the unit cost of disposal would favor conventional landfilling; however, due to the longer life expectancy of a balefill, a life cycle cost analysis (See Table 1) indicated that the cost of disposal on a per ton basis favors a balefill operation over the entire life expectancy of the fill operation. In addition to this cost advantage, the balefill operation has other advantages such as increasing the amount of recycle which is possible in reducing the material placed in the landfill. Any increased reduction by source separation will throw the economic advantage farther in favor of the balefill operation.

REFERENCES


Key Words

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<tr>
<td>Incineration</td>
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<td>Roanoke County</td>
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<td>Roanoke, Virginia</td>
<td>Vinton, Virginia</td>
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