

**High Standard Upgrading and Utilization of MSWI Bottom Ash
Financial Aspects**

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INTRODUCTION

In The Netherlands the utilization of the MSWI bottom ash from Municipal Solid Waste Incineration (MSWI) amounts to almost 100% of that produced. Over the last 10 years, some 600,000 metric tonnes per year have found useful application in road base materials, embankments and the like. Projects with MSWI bottom ash that have been realized vary from 30 tonnes to 1,000,000 tonnes and were ordered by both private contractors and the public sector.

These successful results were possible due to the fact that the following conditions were fulfilled:

1. Allied in an association, MSWI companies have stimulated public authorities as well as the market to introduce regulatory standards for the useful application of MSWI bottom ash.
2. These regulatory measures for MSWI bottom ash have been established by the authorities.
3. The essential physical characteristics for MSWI bottom ash have been agreed with the association of road contractors.
4. High standard upgrading techniques have been applied, in order to obtain a consistent construction material which meets the physical requirements demanded by the market.
5. Certification has been introduced to guarantee mandatory environmental quality, as well as the physical characteristics that are demanded by the market.

PRODUCTION AND UTILIZATION OF MSWI BOTTOM ASH

The principal goal of waste treatment is the reduction of space required for landfill with wastes. As a result incineration of MSW is preferred in The Netherlands. This preference is now embedded in appropriate regulations. Incineration of the MSW results in residues, typically occupying around 10% of the original volume (25% by weight) of the waste. Useful application of these residues reduces the waste, and hence the required space for landfilling, even further. In addition, the heat generated during the incineration process is also utilised; over 0.5 MWh of electrical energy is generated per tonne of incinerated waste.

In 1996 some 3.4 million tonnes of MSW were incinerated in the Netherlands. In 1996 and 1997 several new MSWI's have been or will be completed. As a consequence, the incineration capacity is 4.5 million tonnes per year. Over the last years the amount of MSWI bottom ash per ton of waste has remained essentially the same at 22 - 23 % (m/m); hence the absolute production figures will develop parallel with the throughput of combusted waste.

As Figure 1 shows, for the last ten years almost 100% of the production of MSWI bottom ash in The Netherlands has been utilized. Typical applications are earth and road construction, since MSWI bottom ash is suitable for use in road-base stabilization layers and as embankment material. Given the size of some embankments prepared with MSWI bottom ash - up to 1 million tonnes - sometimes MSWI's keep large amounts of MSWI bottom ash in stockpile for a year before it is required. This phenomenon occurred in 1989 and in 1992, and explains the irregularities in the bar-diagram presented in Figure 1.

COMBINED EFFORT IN THE WASTE PROCESSING ASSOCIATION

In The Netherlands the Waste Processing Association (Vereniging van Afvalverwerkers) is the branch organization for MSW processing plants employing incineration, landfilling and composting activities. The aim of the Association is look after its members' interests with regard to ecologically-sound waste disposal in the broadest sense of the word. This aim is achieved, among other things, by consultations, promotion of research, collective pursuit of quality improvement, exchanging knowledge and experience, and by initiating training, etc. All Dutch MSWI's are members of the Waste Processing Association, and hence the Association is a suitable instrument for consultation with governmental and other authorities concerning future and present legislation.

In particular, with respect to the use of MSWI bottom ash, the Waste Processing Association has proven to be a useful tool in obtaining internal agreement with respect to quality standards. The objective of the Waste Processing Association in respect of MSWI bottom ash is to ensure that it is utilized in a responsible way, both environmentally as well as economically, as a replacement for natural materials. Because of this incentive the Association has shown itself to be an accepted party by other branch organizations, such as the association of road contractors, for making agreements concerning the proper use of MSWI bottom ash from a civil engineering perspective.

POSITIVE APPROACH OF THE AUTHORITIES

Background information

The total consumption of building materials in The Netherlands amounts to around 140 million metric tonnes per year. This consumption - primarily sand, gravel, clay and marl, means a considerable loss of natural resources. Considering that The Netherlands is a small and densely populated nation (compared to the USA 1/250 of the area, but 1/15 of the population) it is the national policy to aim at preserving natural resources; conversely, it aims at reducing wastes to be landfilled in order to preserve space as well. Both aims have led to a positive attitude by the national authorities towards useful application of waste products, such as MSWI bottom ash. At the moment some 15 million tonnes of secondary materials are re-used on a yearly basis, mainly demolition waste and industrial slags.

Like most of all residues to be used as secondary materials MSWI bottom ash also contains some deleterious materials causing potential risk for water and soil. Hence, a paradox exists: the re-use of residues is beneficial for the environment in the sense that it preserves natural resources, whilst the product itself is a potential risk to the environment, through the leaching of contaminants into the ground. To resolve this problem, mandatory measures have been introduced by the authorities for the application of MSWI bottom ash such that any potential hazard to the soil or groundwater is removed.

Scope of the regulatory demands

As a first step in formulating such regulatory standards the Dutch authorities have defined MSWI bottom ash as the product of MSWI's operation according to the following principles:

- operation is according to the present regulations and authorizations
- only MSW or comparable wastes are processed
- in general any hazardous waste is excluded from the process.

Required environmental quality

With respect to the environmental quality the government has decided that MSWI bottom ash should comply with the following requirements:

- free of fly ash (MSWI bottom ash and fly ash are collected separately, and no combined ash is produced)
- storage for at least 6 weeks prior to application
- leaching behaviour should comply with specific standards
- scrap metal content less than 5% (in order to promote the re-use of scrap metal)
- loss on ignition (LOI) less than 6 %
- digestible material less than 2%

Permitted methods of utilization

Finally, guidelines have been formulated for the way in which MSWI bottom ash may be re-used:

- in its application the MSWI bottom ash has to remain at least 0.5 meter above average maximum groundwater level
- use is prohibited in soil or groundwater preserved areas
- measures have to be taken to prevent the infiltration of rainwater into the MSWI bottom ash
e.g.: an asphalt top layer (road pavement) in case of use as a road-base material or
a 200 mm. thick sand-bentonite top layer for use as a bulk fill material.
- a side and top layer has to be applied within 6 weeks after the application of the MSWI bottom ash to prevent infiltration of (rain)water
- where possible the material should be used in larger projects and the location of such projects recorded

In summary, the existence of these guidelines and regulations has shown to be of the utmost importance in order to convince decision makers for civil works to accept MSWI bottom ash instead of sand or gravel. Lack of guidelines or insufficient guidelines are fatal for the market-acceptation of secondary materials. Since national and local authorities as well as municipalities have acted as pioneers in the use of MSWI bottom ash, market-acceptation has steadily grown.

Next to market acceptance, also marketing of MSWI bottom ash is an important factor. Due to limited availability (time, quantity) of secondary materials, design of consultants are generally not based on implementation of these materials. Therefore specific marketing and engineering has to be performed by companies having knowledge of civil and building industries.

REQUIRED PHYSICAL QUALITY DETERMINED BY THE MARKET

In order to improve the acceptance of MSWI bottom ash as a building material, a potential client has to be convinced that the use of the material is equivalent to the use of primary materials. Criteria for the physical quality of MSWI bottom ash have been defined in close co-operation with the association of road contractors in The Netherlands on basis of the existing criteria for primary materials.

In addition to the environmental demands, the following criteria have been formulated:

- crushing-resistance factor ≥ 0.65
- granule size according to Table 1

Furthermore, pilot projects have been selected to demonstrate the applicability of MSWI bottom ash in earth or roadwork.

CERTIFICATION OF MSWI BOTTOM ASH

History

Quality control and quality assurance can be regarded as the reason for the present success of MSWI bottom ash in Holland in recent years (Figure 2). Already in 1987 the procedure for certifying MSWI bottom ash had commenced; an independent certification institute was tasked with formulating specifications to which MSWI bottom ash should comply. In February 1989, using the expertise of a number of specialists, this certification institute introduced the definite specifications for MSWI bottom ash. Since that moment the individual MSWI's prepared a framework of internal quality control in which the acceptance of the waste, permits, procedures, process conditions, MSWI bottom ash handling, storage and inspection have been regulated.

Sampling and testing of the product

The physical properties of certified MSWI bottom ash are specified based on guidelines given by the association of road contractors in 1988. The environmental specifications (mainly leaching behaviour and measures required to prevent soil contamination) should comply with the present Dutch regulations formulated in 1986.

As part of the quality control, samples of processed MSWI bottom ash are taken 1 to 2 times a day during a production period of two weeks. In general one sample is analyzed per 5,000 to 10,000 tons of MSWI bottom ash.

In order to obtain a certificate for MSWI bottom ash, the operation of a MSWI must comply with certain rules:

- The environmental quality of the MSWI bottom ash is periodically monitored by an independent laboratory which reports the results to the certifying authority
- The physical properties of the MSWI bottom ash is periodically monitored by an independent laboratory

Random inspections by the certifying institute make sure that specifications are met at all times. Once a MSWI is able to demonstrate its compliance with these regulations for some time the certificate will be awarded.

The certificate guarantees both the physical and environmental quality of the MSWI bottom ash to its users. Consequently, batch-like inspections for the quality of the material are unnecessary, saving both money and time for the customers.

Costs related to certification

Although certification has many benefits, its financial benefits are hard to quantify. Often producers of secondary materials refrain from seeking certification because of the costs. The Waste Processing Association regularly obtains information from its members to monitor the costs of physical and leaching tests. These costs, together with the fee for certification, may be related to the tonnes of MSWI bottom ash. As shown in Figure 3, the total costs of certification of MSWI bottom ash have reduced over the last years, due to the strong competition between environmental laboratories in The Netherlands. Every two years the Waste Processing Association invites laboratories to bid for the required tests. The costs related to certification amounted to some \$ 0.20 per tonne in 1996.

FUTURE DEVELOPMENTS

Dutch legislation for building materials is currently under review. In 1998 new legislation (Building Materials Decree) will be enacted which also applies for MSWI bottom ash. Briefly new leaching tests will be introduced combined with considerably stricter demands. Within this new legislation the present quality of MSWI bottom ash sometimes cannot meet the general standards for building materials. The utilization of MSWI bottom ash in bulkfill however will be allowed by incorporating double protective top and side layers, structural concrete or asphalt concrete.

The Waste Processing Association realizes that this may hamper the utilization. Hence, it is concluded that the quality of MSWI bottom ash has to improve up to the general standards given in the new Building Materials Decree. In 1997 pilot-plant experiments will be performed to validate several techniques to reduce the leaching of the MSWI bottom ash. Furthermore the certification program will change according to the future legislation.

UPGRADING OF MSWI BOTTOM ASH, FINANCIAL ASPECTS AND PARAMETERS

Introduction

Next to policy aspects, as described before, also cost-effectiveness forms an incentive for high standard upgrading and utilization. The MSWI bottom ash used to be landfilled, until environmental legislation and lack of space caused an increase in landfill rates. This disturbed the economics of incineration plants and consequently processing the MSWI bottom ash to re-usable materials became worthwhile.

The processing activities finally resulted into the erection of large scale plants where both MSWI bottom ash and also ferrous and non-ferrous metals were regained in a high quality.

This section shows the different general parameters which form the financial criteria for the upgrading and utilization of MSWI bottom ash.

Basic applications for MSWI bottom ash

Disposal as landfill lasted for many years, until development of environmental consciousness and the "Not In My Back Yard" syndrome, caused a significant rise in landfill costs. Sophisticated and upgraded utilization of MSWI bottom ash was found in the infrastructure, where the ash could be used as a substitute for bulk sandfill.

This new market was supported by thorough research and several pilot projects, and the results were used for legislation and certification. The results of this legislation and certification are discussed before, but the principles can also be seen in the financial aspects of the use of MSWI bottom ash. Usually the buyer receives a gate-fee, which has a triple purpose:

- payment of the costs of transportation from incineration plant to the project and workmanship
- payment of the isolation measures in its final application
- compensation for future removal of the MSWI bottom ash

The level of this fee also depends on the current price for sand fill (approximately \$ 7 per cubic m.), since MSWI bottom ash is a substitute for this material. In The Netherlands the gate fee can be as high as \$ 8 per tonne of the MSWI bottom ash.

Basic recycling solutions

Recycling plants must be capable of producing a granular material with a particle size of maximum 40 mm. Furthermore, these plants must be able to separate the ferrous and non-ferrous metals.

The amount of retrievable ferrous metals in untreated MSWI bottom ash can be up to 9 %, non-ferrous metals up to 0.65 %.

Because these materials give a positive revenue (depending on world market prices and the purity of the metals), upgrading plants form a combination of screening, crushing and magnetic activities.

The block schedule of such a plant (see Figure 3) is based upon the production of a high purity of ferrous and non-ferrous metals.

Financial aspects

To obtain a general view of financial aspects involved in upgrading of MSWI bottom ash and utilization of produced materials the following breakdown can be given.

Processing costs: fixed

- processing area: area required for the recycling plant (interest on capital)
- infrastructure: roads, storage area (interest and depreciation)
- stockpile area: to bridge the production capacity of the incineration plant (continuously, relatively low capacity) to the quantities required for infrastructural projects, a stockpile having a capacity of at least half a year production is required; this stockpile area also includes watersystems and sump (interest and depreciation)
- processing plant: mechanical, electrical, control and foundations (interest and depreciation)
- buildings: isolation (noise, dust) and protection (wind, rain), (interest and depreciation)
- labour: costs of employees (salary costs)
- repair and maintenance: a part of the repair and maintenance costs are independent from production (cleaning, maintenance contracts, spare parts, painting)
- equipment: shovel, dumper and various (interest loss and depreciation)
- miscellaneous: (insurances, taxes, certification, management fee, spare parts in stock, etc.)

Processing costs: variable

- repair and maintenance
- consumables: wear components, electricity, gas, oil
- labour: costs for temporary employees
- miscellaneous: (internal transportation, weighing, certification, etc.)

Material sale costs (including management fee)

- Fee gate for MSWI bottom ash
- Revenues for ferrous metals
- Revenues for non-ferrous metals

An example is given in Table 2, based upon the following parameters:

- capacity: 100,000 tons MSWI bottom ash a year
- labour: one shift of 40 hours per week
- costs for labour, investment, etc. are referring to Dutch circumstances
- anticipated investments:
 - total area: \$ 600,000 (10,000 m²)
 - infrastructure : \$ 250,000
 - building: \$ 500,000 (30 x 40 x 10 m)
 - processing plant: \$ 2,500,000
- Parameters:
 - lifetime upgrading plant 10 years

- percentage of interest: 8 % annual

Restriction

Typical Dutch investments are higher. In The Netherlands MSWI bottom ash recycling plants are built on the premises of incineration plants in dense populated areas usually having to comply with technical, environmental, architectural and availability demands of a round the clock incineration procedure.

CONCLUSIONS

Successful utilization of MSWI bottom ash requires a constructive approach of all parties involved. Existence of generally accepted environmental and physical quality standards is essential. Certification is a useful tool to facilitate the acceptance of the material in the market. Certification also helps to profile MSWI bottom ash as a well defined building material of uniform quality nationwide.

Table 1. Granulometry of certified MSWI bottom ash

coarse type on sieve	roadbase material	roadbase material	embankment material
	(0/20) unbounded % (m/m)	(0/20) cementbound % (m/m)	(0/40) % (m/m)
45 mm	0	0	0 - 10
22.4 mm	0 - 10	0 - 10	-
8 mm	10 - 40	10 - 40	-
2 mm	40 - 70	30 - 70	-
63 µm	92 - 100	-	92 - 100

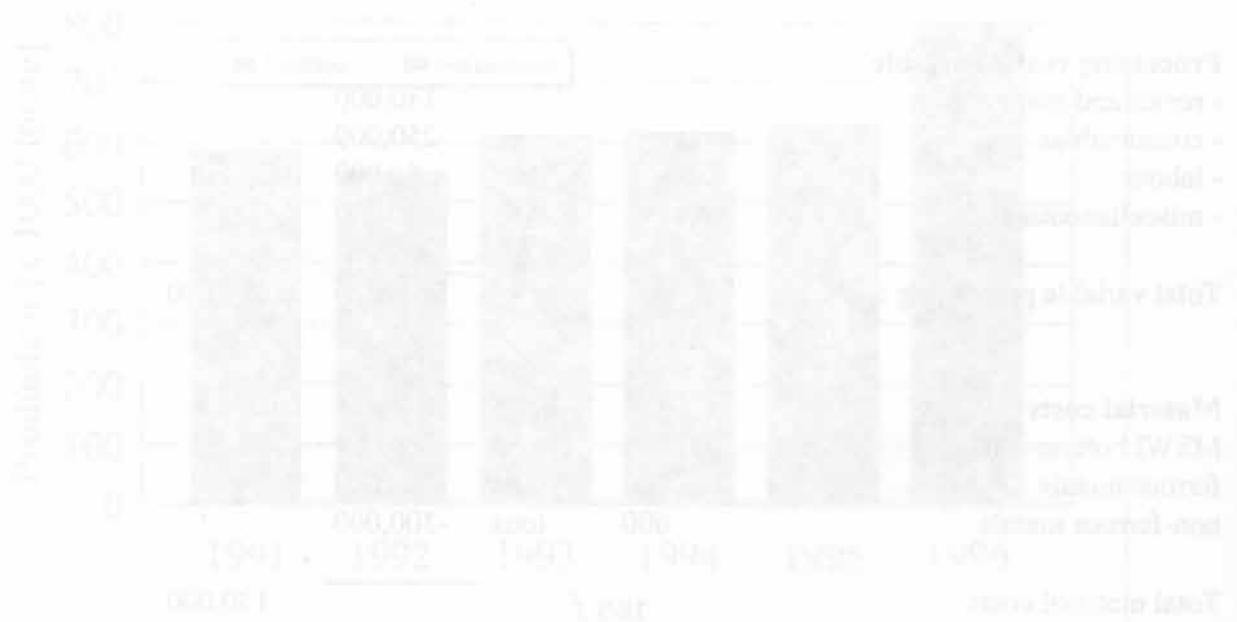


Table 2: financial aspects of upgrading and utilization

Description	Quantity	Unit	Price \$	Total \$
Processing costs: fixed				
- processing area	2,500	m2	30,000	
- infrastructure			40,000	
- stockpile area	7,500	m2	70,000	
- processing plant			330,000	
- buildings			70,000	
- labour	5	persons	190,000	
- repair and maintenance			30,000	
- equipment			40,000	
- miscellaneous			150,000	
				+
Total fixed processing costs				950,000
Processing costs: variable				
- repair and maintenance			130,000	
- consumables			250,000	
- labour			50,000	
- miscellaneous			100,000	
				+
Total variable processing costs				530,000
Material costs				
MSWI bottom ash	90,900	tons	730,000	
ferrous metals	8,500	tons	-300,000	
non-ferrous metals	600	tons	-300,000	
				+
Total material costs				130,000
TOTAL				1,610,000
Landfill	100,000	tons	50 \$/ton	5,000,000

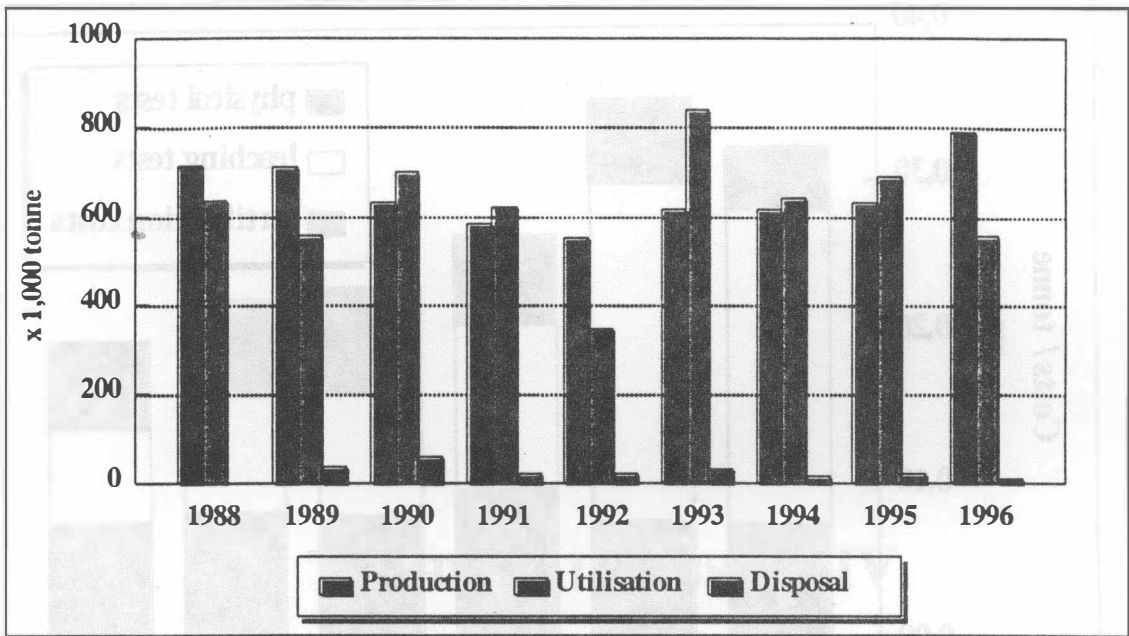


Figure 1. Amount of MSWI bottom ash in The Netherlands

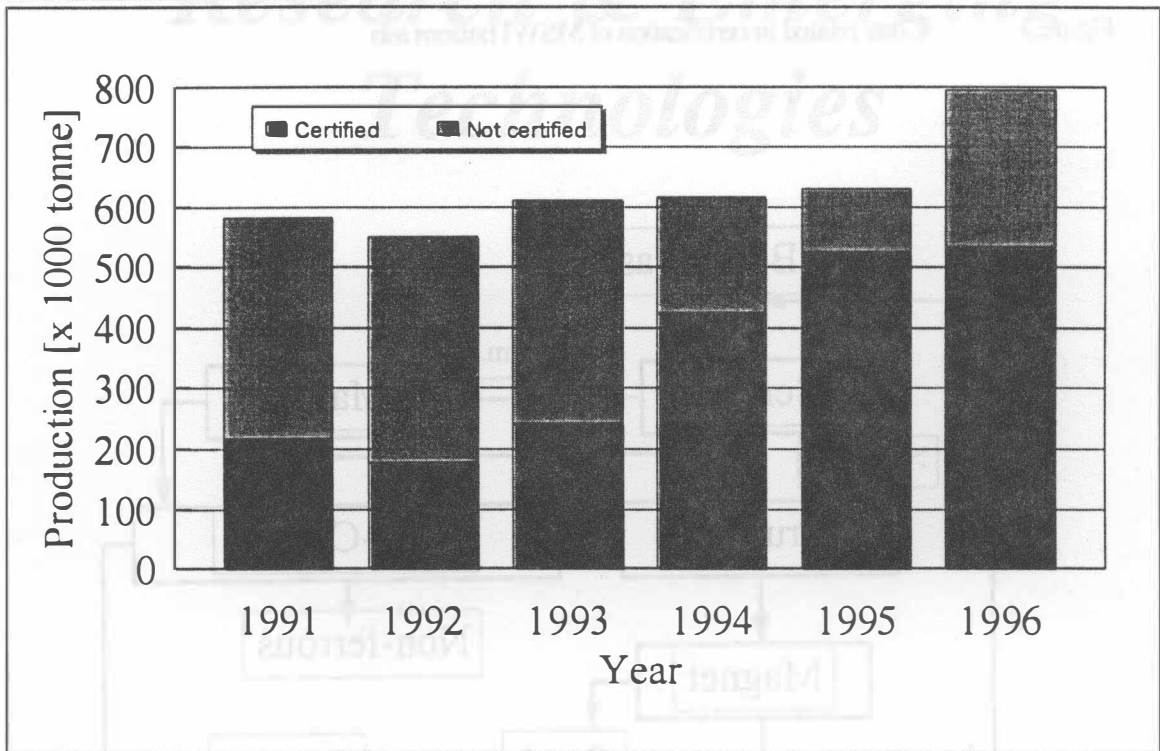


Figure 2. Production of MSWI bottom ash, fraction certified

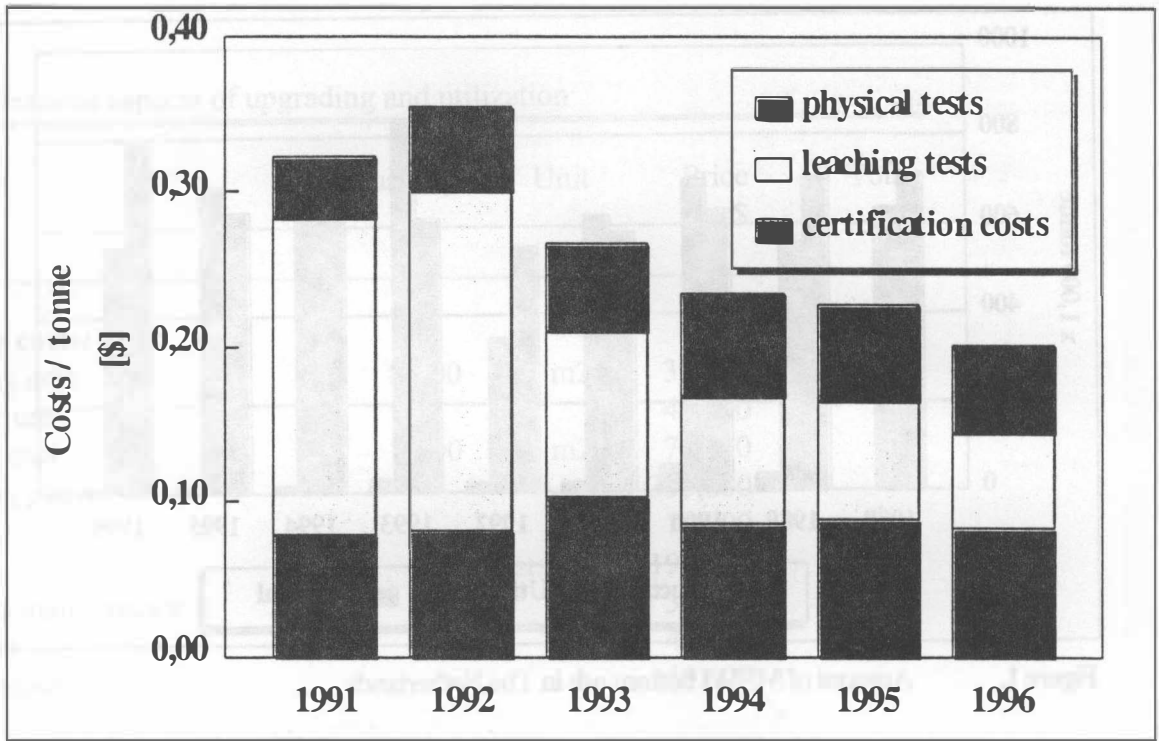


Figure 3 Costs related to certification of MSWI bottom ash

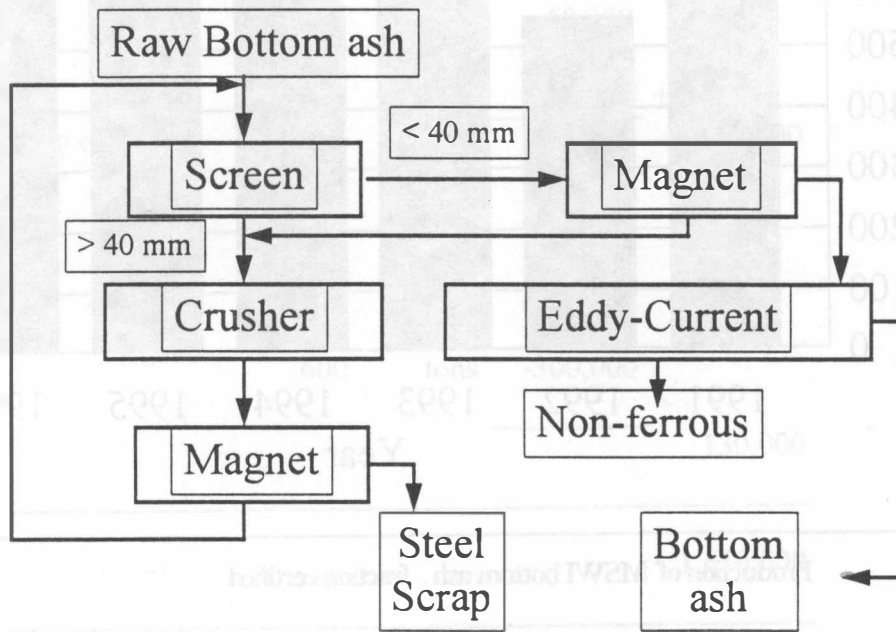


Figure 4 upgrading of MSWI bottom ash: block schedule