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THE DYNAMIC NATURE OF MSW MANAGEMENT

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ABSTRACT

The MSW problem is defined. Management models of different countries are discussed. The contribution of engineering to waste handling is described by typical examples. The necessity of good and dynamic management practice is shown. The inefficiencies of some established management methods from an engineering point of view are demonstrated. Particular difficulties encountered in improving established practices are described. A conceptual model for handling MSW is developed that may be used as base case for a variety of locations. It avoids all identified inefficiencies. A South American situation forms the background for the model. Local conditions of informal economy are incorporated to advantage. Public participation is obtained through selected test units. Further experimentation is indicated. Candidacies from interested towns are invited to test the model.

INTRODUCTION

Municipal Solid Waste (MSW) handling has evolved over the years to be now understood as applying the most advanced technologies available, all things considered. Research in Brazil, observations in various other countries, and the study of the literature have produced a rather unfinished picture of the state of the art. There remain conceptual differences in the world about what is considered appropriate technology and management. Is it appropriate to have the municipality actually handle the waste, or should it pay third parties to do this? Is the standard municipal tax pool adequate to cope with satisfactory waste treatment, or does the handling system have to levy its own funds? How much longer can landfills accommodate the waste and at what cost? How much initiative may be expected from the community and how much from public administration? Although engineers generally agree on the appropriateness of closing the mass balance for industrial undertakings, short-term technical solutions to waste accumulation do not always reflect this philosophy. Micro-scale problems, such as closing the life cycle of a single product or commodity, more often than not obscure macro-scale considerations of the planetary heat and mass balance. Life-cycle considerations are specially fragile when it comes to construction and demolition material that cannot be returned to its original state in nature. This is where the crucial question of competence comes into play. Is MSW a technical or an administrative problem? Science and engineering as disciplines have always professed the profitable satisfaction of human desires or of induced needs. MSW as a commodity is demonstrating very eloquently for the first time that there are limits to this satisfaction, and that these limits are being exceeded right now. This is a new and unexpected situation for traditional engineering science.

In the context of this critical appreciation, what follows pretends to look at MSW as an as yet unsolved managerial problem, to the solution of which the *engineering* contribution is insufficient. From there, a possible management model is developed that might be apt to function as guide or basis for the development of individual or collective approaches to MSW in various parts of the world. Of necessity, the discussion centers on cultural and economic conditions prevailing in Brazil, but many of the arguments may be valid in other parts of the world with appropriate adjustments.

THE PROBLEM STATEMENT

Included in the definition of MSW are common household waste, garden trimmings, material collected in the park and street cleaning process, hospital trash, construction debris and residues from commercial and public establishments. Industrial waste handling and treatment obeys its own norms, technologies, and management guidelines, and therefore is not normally included in the problem statement of MSW. At an inexorable and dynamic generation rate, which for household waste alone at present stands at approximately 0.8 kg per person per day in the South [1, 2] and in excess of 1.6 kg per person per day in the North [3], any engineer is probably intrigued about the mass balance. This author chooses to state the problem in terms of the relativity between two planets that so far coexist peacefully on Mother Earth: the principal planet on which life thrives, and the parallel planet which consists of the inanimate material resulting from human activities. This parallel planet receives MSW, industrial waste, sewage, and contaminated air. It is forever growing at the expense of the principal planet, does not support life, and represents the open end of the planetary material balance. Good environmental impact assessments and their audits control the landfills, but do not avoid their continuous growth [4].

Micro-scale closed life cycles of a few selected materials or consumer items are obviously insignificant within the global dimensions of the parallel planet. As closure of all product life cycles is not a realistic expectation at this time, the gap in the material balance will keep growing. The situation is now irreversible. The problem at hand is thus defined as finding ways to alleviate the burden of MSW, in contrast to the impossible proposition of making it disappear [3]. This study hopes to make a modest contribution to the development of policies, procedures, and management models that aim at reducing the quantities of MSW irreversibly going to the parallel planet. The problem statement insists on management models for the following simple reason. The prime purpose of engineering today as in the past is to take raw material from the principal planet and transform it into consumer goods of ever decreasing life expectancy. The engineering profession has also produced excellent equipment for taking away the used consumer goods from the principal planet and deposit them on the parallel planet where they will remain. Good profit is made on both operations. Pragmatically speaking, there is no valid economic reason for closing the material balance gap, from an engineering point of view at this time. Behavior management is the appropriate tool to achieve at least a partial reduction of waste accumulation.

A SAMPLE COLLECTION OF EXISTING APPROACHES

The dynamic nature of MSW management becomes apparent as soon as one starts to observe and study the models used in different countries, and tries to find common traces which are not there. Furthermore, induced by certain conditions, any community may choose to switch from one model to another at any time. Experimentation is still in progress [1, 5-10]. The examples that follow have no pretension of capturing the whole truth about any observed situation. They are meant to illustrate the difference of approaches and the absence of consensus or of a reference situation. Bulk incineration has been observed by this author in Sweden, bulk landfill in Argentina, and bulk anaerobic digestion in Canada. Mixed waste street collection has been observed in Great Britain, Argentina, and Brazil, and selective street collection in Germany. Coexistence of bulk and selective street collection has been observed in Canada and in Sweden.

Limitation of waste collection to fixed container capacities has been observed in Great Britain and in Germany. Bulk street collection is paid for by the street block in Argentina and by weight in Brazil, whenever it is delegated to private enterprise. Compacted mixed waste sorting facilities have only been observed in Brazil. The literature reports experiments with mixed waste processing facilities (MWPF) also in the United States [10, 11].

Surprises are waiting for any individual who tries to internationalize his or her experience, due to the lack of a reference situation which is so common in other fields of endeavor. At the initial stages of his research on the subject, this author presented an optimized waste handling model based on mixed waste sorting to a European audience, only to discover that this type of model had been discarded in Europe. The inverse may be equally true. Anyone advocating selective street collection in South America will find obstacles of cultural and social origin that in Europe do not exist. Over the years it has become evident that transfer of technology or of management practices is largely inappropriate due to the wide variety of idiosyncrasies, climates, states of development, and even living comfort expectancies prevalent throughout the world.

A couple of fundamental truths crystallize from all observations and could form very modest common parameters. First, at this time no product is marketed with the cost of final disposition or recycling contained in the sales price. Municipal sales taxes are not normally earmarked for waste disposal. Consequently, apart from a very few items that can economically sustain their recycling cost, MSW is still a sink, and not a source of revenue. It remains to determine where the money for handling it comes from.

Second, as neither recycling nor incineration or digestion completely eliminate waste, some type of landfill is always needed to close the operating cycle. Logically, bulk landfill is the worst, and bulk incineration the best alternative in terms of final disposal volume. The fallacy of this comparison is the apparent closure of the total mass balance. As carbon dioxide transports matter from soil to atmosphere, some process has still to be created to bring it back. Research is presently carried on in various locations that intends to deposit it in the oceans, until a better process can be found [12]. The result could be termed oceanfill, in contrast to landfill, but it does not close the operating cycle.

Third, at present a common trend in the North is to drastically reduce landfill volume. *Diversion* is the technical term used which means that waste needs to be diverted from landfill to other destinations. This is achieved primarily through command and control mechanisms. High fees are charged for material deposits at the landfill sites, or deposits of certain items such as organic matter are flatly forbidden by law [3, 6]. The diversion routes are composting of organic waste [7-9, 13-15], recovery and processing of construction and demolition debris [16-19], source separation of various types [20], bulk incineration [21, 22], anaerobic digestion [23], and Pyrolysis [24]. It is noteworthy that Southern countries have not yet reached the stage of recognizing diversion as an inevitable route to a sustainable future. Both Brazil and Argentina, to this author's personal knowledge, are still in the era of toll free and unrestricted landfill. Unfortunately, information on other regions is scarce (1, 25].

Although most specific technologies and management practices do not lend themselves to export or transfer from one region to another, it is this author's conviction that the philosophy of diversion will become accepted worldwide. The only independent variable here is time: the time required for the waste generation rates in the South to catch up with those in the North. The dynamic nature of MSW management is thus demonstrated. Changing life style and changing environmental burdens continuously increase the demands on waste management.

TECHNOLOGY AND COMMON SENSE

The basic technology at the collection end of the household waste handling process has been for a long time the vehicle that receives the mixed trash at the doorstep by manual loading and compresses it with hydraulic devices into a fairly homogeneous compact humid mixture. This is true for entities which practice bulk street collection, either exclusively or in combination with selective collection. In the latter case, selective collection is optional and thus increases the cost of the handling operation. In effect, two separate fleets of vehicles and a special set of containers have to be operated and maintained. The collection model is quite dynamic. In the case of exclusive bulk collection, the hydraulic truck is not always designed to carry away every imaginable item of trash, and is not always equipped with a hydraulic lifting gear. In the case of exclusively selective collection, a completely different kind of vehicle is necessary. On German streets, e.g., one can observe compartment trucks with hydraulic lifting devices that carry two or three different trash items, one in each compartment. Selective collection of necessity requires a container for each item. Every household, apartment building, or commercial establishment has to maintain a fleet of containers which are adapted to the lifting gear of the trucks. The containers have wheels, such that the physical effort of the collection crew is limited to wheeling the containers from the curbside or the front yard to the truck parked at this same curbside. Now compare this to the situation observed in Brazil and Argentina who practice bulk collection. No special containers are mandatory there. The trash is left at the curbside in any arbitrary way, loose or in plastic bags, and the trucks have no lifting gear. In order to reduce the state of war at the curbside, many apartment buildings use 300-liter metallic barrels to store and present the trash. Those barrels, when full, may weigh up to half a ton each, and have to be carried to the truck and lifted to the receiving bin manually. Appropriate technology which would alleviate physical human effort is still wanting. In tropical climates where the deterioration rate of organic waste and the population of wandering dogs and cats are quite high, the curbside at times represent odorous and visual insanity.

Construction debris in Brazil are handled by private enterprise in special containers that are hauled to the curbside and removed when full, according to the orders of the users who pay for transportation. The problem with this system is that the containers sit at the curbside next to a construction site for many hours and are open. All kinds of people throw all kinds of trash into them during this time. At the end, they constitute nothing but a parallel mixed waste collection system, independent from municipal crews and with the wrong destination. The material is used as landfill in various parts of the township where only inert matter would be acceptable. The literature reports experiences in the United States and in Europe that aim at diverting this type of material from landfill altogether. It is separated and finds recyclers. Although experimentation is still in process, the common sense diversion philosophy has induced the appearance of technical solutions [16, 18, 19].

At the destination end of the collected waste, the situation is just as dynamic and heterogeneous. Bulk landfill is one usual destination of mixed household waste collected in bulk at the curbside. In Brazil several towns operate a sorting plant which represents a stopover between street and pit. A municipal incinerator is a second option for this same mixed waste. Swedish towns visited by this author operate impressive installations of this type that produce warm water for the district heating network. In Canada, biodigestion sites produce methane from the waste, which is a third viable option. Technically, it is similar to landfill which also produces methane, although this is not its prime purpose.

Some engineering common sense tests have been applied to several parts of these waste handling systems. The results are presented here to exemplify. They are not yet complete for want of further observations, but they are sufficient to arrive at some preliminary conclusions. The manufacturers of collection trucks and sorting plants do good engineering work to come up with the exact equipment asked for by the users. If the user of a compacting truck does not ask for a hydraulic lift, that is not a problem of the manufacturer. Organic matter cannot be compacted in the trucks. Its natural apparent density is already close to the maximum possible when it arrives at the curbside. In Brazil, the content of organic matter in household waste is in the 70 percent by weight range [2]. This means that a ten-ton-truck is acquired and operated to compact three tons of dry waste per trip: a very profitable situation for the truck manufacturer. The truck, in essence, produces a perfectly mixed wet product. The manufacturer of a sorting plant is laughing, too. His very existence depends on the high degree of mixing of the incoming waste. In fact, the feed system to the plant contains two more mixing steps disguised as *plastic bag openers.* A long conveyer for sorting; magnets for ferrous material; and hydraulic presses for paper, plastic, and aluminum complete the installation.

The common sense test at once reveals the reason why this type of installation and management method is not used extensively. A sequence of perfect mixing equipment followed by another sequence of perfect separation equipment is thermodynamic nonsense ordered by administrators and built by engineers. This is the most famous case. Less than a dozen towns in Brazil operate such a facility, and the literature reports on their existence in the United States. There, according to reports, they have known ups and downs and are far from being definite options for MSW management [10]. Mixed processing facilities (MPF) receiving only dry waste are much more common [7]. They represent a more logical option than MWPF. Our own research has led us to agree with the technical and managerial principle behind them.

A few minor tests reveal that even in mandatory selective collection systems, it happens that items are removed separately from the curbside and dumped into the same landfill, depending on the sporadic values of admission tickets to the various possible destinations available [26].

Incineration, at first glance, looks like the most elegant method of waste disposal. What is left over is surprisingly little. Even so, in many places public opposition to incinerators is strong. The common sense test in this case is complex. Good arguments are available to both parties. In some of the observed cases, only hospital trash is incinerated in installations that are plainly designed to consume the maximum possible amount of pure oxygen supplied by specialty chemists [2].

The technical options are abundant, the good solutions are scarce. It seems obvious that any municipal administrator will be hard put to decide which is the correct model for his or her town. This author has been approached by engineering companies from Europe interested in selling waste handling equipment to South America. The answer has so far been pragmatic: Equipment alone will not do. A sound management model will have to come with it to avoid the thermodynamic pitfalls. And this opens the next topic.

MANAGEMENT DEMANDS

The principal argument that permeates this study since the beginning is that MSW is the first real test for modern professional course curricula. Engineering as an *exact* science has been trapped by the basic laws of thermodynamics that state: *if you can avoid it, do not mix anything.* Neither has engineering been able to provide the interface between equipment and people. Consequently, the student of the topic MSW turns to administration or management theories for answers. The argument is that people produce waste and deposit it at their doorstep. For any of the described models of handling or treatment, the first step is to manage people, not to build equipment. People have to be told and convinced how and where to deposit their waste. This is the most important part of the whole model: the feed or input. In many instances, public administrators have failed simply because they have been unable to manage the MSW transport from the kitchen to the front door of households.

A command and control model that sells a specific container to every household and only collects waste in this container, is a reasonably successful management model. It leaves no degree of freedom to chance. It controls the input to the waste handling system. On the other hand, a loose model that only initiates its action with the collection crew, is a failure. The best process cannot function if the feed is inadequate. This is the first argument which leads to the conviction that MSW is a management problem.

After the input is determined, a model has to define the processing steps and the output. If a model considers bulk collection and bulk landfill or bulk incineration, there are no intermediate steps. The model only needs to define the cost of the operation and the parties involved: who runs the fleet of vehicles and who operates the landfill.

As soon as additional parameters enter the model, such as selective collection or post-collection sorting, more administrative effort is required. An accounting procedure accompanies every waste item or every operating step in the model. Some basic administrative tasks are scheduling of collection, correct destination of collected items, operation of sorting facilities, and commercialization of products.

At the output invariably stands a landfill, a biogas handling system, a composting facility, or an incinerator. These operations are equipment intensive and are placed into the hands of engineers.

This empirical overview of some of the models shows that the areas requiring managerial skills are the input and the processing steps. The model described in the next section considers this necessity. It specially attends to the input as the most important administrative parameter. The processing steps are largely left for free enterprise to handle with minimum intervention of public administrators.

The fact that management strategy has to respond to local conditions is vividly demonstrated by the enormous variations of project and operating parameters. Mixed household waste composition may serve as an illustrative example. Sakai [3] reports the following weight basis organic matter contents: Japan 42 percent, United States 23 percent, Sweden 45 percent, The Netherlands 30 percent, Germany 27 percent, Canada 29 percent. This is very different from Brazilian conditions and possibly from those in other Southern countries as well. Our research shows organic matter to represent an average 70 percent of household waste by weight. Differences in culture and living standards have surprising effects on waste composition. Evidently, diversion efforts in Brazil, when compared to those in the industrialized countries cited, belong to a different order of magnitude. Management strategy will have to reflect this situation.

MODEL DEVELOPMENT

The aim of ongoing research at this author's location is to devise the best possible management model for a given situation. The model should take advantage of local conditions and existing infrastructure, but its conception should be logical and general enough to serve as basis for other models responding to different local parameters. Of necessity, the study considers primarily Brazilian parameters.

General objectives to be met are:

1. Achieve maximum feasible amount of recycle.
2. Determine the ultimate destination of final waste in accordance with its composition at the output end of the model, with landfill as temporary option.

3. Minimize the educational effort required at the input end.
4. Control curbside conditions.
5. Include all types of MSW in the model. Identify components by material and by utility.
6. Avoid thermodynamic and administrative nonsense.
7. Make the best use of existing infrastructure in terms of both equipment and people.
8. Involve the population in the operation.
9. Build and use example cases for propagation of public participation.
10. Keep the cost of the operation to a minimum and distribute it adequately between all actors.

The existing infrastructure at the sample location consists of a rudimentary mixed waste sorting facility (MWPF), terrain for open air composting, a weigh scale for trucks, a landfill which is geographically misplaced but is operated under reasonable conditions, a fleet of twenty-seven hydraulic compacting vehicles for mixed waste, a fleet of container hauling trucks with containers for construction residue. The location has approximately 400,000 inhabitants who on the average generate 0.63 kg per person per day of mixed waste and some 800 containers per month full of construction and other residue. There also exists a network of informal garbage pickers operating in the streets who report to a wholesaler of used paper, board, and plastics.

In a typical *top-down* management procedure, the municipal administration specified the technology to be used for collection, processing, and landfilling of the waste. It then selected and hired a private company to run the operation against a tonnage fee. The model that results from the premises listed above inverts the procedure. According to objectives 8 and 9 it pretends to implement a *bottom-up* philosophy where guided initiatives of the population rank ahead of technology choices and waste handling contracts.

Objective 1 depends heavily, in fact almost exclusively, on the management of the input to the model which has already been identified as the most critical point. Obeying the laws of thermodynamics (objective 6), common sense, and considering the network of informal pickers (objective 7), it is evident that a minimum of pre-collection sorting is required. Objective 3 prevents this sorting from being elaborate, time consuming, and costly. The solution is a simple two-bin sorting system in which the population is asked to separate perishable or putrescible organic waste from all other waste and deliver these two items separately to the curbside. No cost is associated with this, as no special containers are required. Transparent plastic bags are used to accommodate the food residue, for ease of identification. No labeling is needed. The bags are those which people receive at vegetable markets to carry home their fare. A few selected streets are used as guinea pigs to create the example that may be imitated all over the town once it is deemed satisfactory (objective 9).

Media time and space presently occupied by the municipal administration for publicity, is liberated to convey to the population simple explanations of the reasons and expectations of the model (objective 8). As far as containers for construction residue go, a first attempt at controlling their contents is to require a lid or some other cover put on them, and to prohibit the transport agent to carry the containers away if common trash is found in them (objective 5). With these simple, logical, and common sense measures, the input to the model has been taken care of. The waste is now available at the curbside in such conditions as to facilitate collection and sorting (objective 4). No expense to the municipality has occurred, and no engineering work has been required. Only management procedures were used.

The first processing step of the model concerns the removal of trash from the curbside. Here, some large scale testing will be necessary to check the model pretensions which are the following. Construction residue containers are removed as usual, with the only request of prior visual inspection. Organic putrescible waste is collected once a day at predetermined hours. Only waste contained in closed transparent plastic bags is accepted. Households or establishments are responsible for seeing to it that the bags are not opened while at the curbside. This is possible by correct timing and appropriate location of the bags. The organic waste is transported without compression.

The dry waste left at the curbside which is not subject to biological deterioration, is collected once to twice a week according to the section of town and historical quantities observed. Again, collection hours are communicated. In this case, no protective measures are required. No food items are present that would attract animals. Informal pickers will pass by and carry away certain items, which is the first sign of their quite natural inclusion in the model (objective 7). Transportation of this dry waste may be done by the existing hydraulic compression trucks, but as more recycling possibilities appear, other types of vehicles will be asked for by the sorting crew and will quite naturally enter the scene. Also, as only dry waste is delivered for sorting (MPF), the management of the present facility (MWPF) will be adapted naturally. More customers will appear for separated items due to their improved quality. As feedback to the collection step, additional curbside separation of specialty items such as light bulbs and electronic equipment may be asked for.

The second processing step of the model concerns the destination of the three basic trash items carried away: organic waste, dry waste, and construction residue. The model calls for maximum possible recycle (objective 1). Accordingly, the destinations have to cater to recyclers. The model uses the site of the present mixed waste sorting plant as destination (objectives 7 and 10). The operation is licensed to three service companies who take care of the three trash items and organize the recycling activities. The putrescible waste is composted in the open air by appropriate procedures. It is complemented by certain appropriate items from the dry waste such as paper and wood which do not find interested takers.

The finished compost is screened to retain inerts which go to landfill. The dry waste is run down the sorting conveyors of the plant and is manually sorted. Ideally, this operation is open to the informal garbage pickers and to other interested parties who pay for what they take away. Recycling is determined by market forces. No command and control method applies. This is a *bottom-up* model which relies on private initiative. What is left over at the end of the belt is taken to landfill. The construction residue is sorted and processed according to market demand, with appropriate equipment and procedures still pending. Leftovers go to landfill at locations indicated by the municipal administration.

The model assumes that hospital trash is incinerated at the source without public intervention.

EXPERIMENTATION AND PERSPECTIVE

Experimentation with the model has been started. The first guinea pig communities are being involved. The project is a long-term enterprise whose speed of progress depends heavily on available funds and administrative support. Any town may be a candidate for the experiment. As there are no two completely equivalent locations, the model will do exactly what it was built for: from basic concepts and given parameters, it will adapt itself to every case.

What has been achieved with this model? Public expenditures and participation of the municipal administration has been kept to the strict minimum. All existing infrastructure has been integrated. The population has been identified with the model and may measure the value of participation. Recycling is left to private initiative for best results. All ten objectives have been met. Many details still need to be attended to which will occur naturally as a consequence of experimentation. A few breakthrough results are inherent in the model. First, on separating the organic waste at the source, its contamination with metals is avoided. This has been one of the prime objections to compost in various countries. Inside the household, odors are controlled due to the instant separation of organics in the kitchen. The situation at the curbside is acceptable. The number of volunteer units is rising fast. With a surprisingly modest media effort, spontaneous public cooperation has occurred. This contrasts with the expectations of the municipal administration that legislation and policing would be required. Second, the whole recycling operation is in private hands and thus is governed by the market. No thermodynamic nonsense develops. The diversion achieved is also surprising. The original 100 percent of household waste going to landfill has been divided into 70 percent compost with 10 percent leftovers, and 30 percent dry garbage half of which is recycled. Total result: 75 percent diversion.

The perspective is quite optimistic. Any town that has the disposition to try the experiment, will solve its MSW problem in a reasonable time. Little engineering, but a great deal of administrative creativity are necessary to win this game. This author actively seeks candidate towns or other social units to apply the model, in order to improve on it.

CONCLUSION

MSW is an international problem of great magnitude. No standard solutions are available. No reference situations exist. Every community uses its own model to manage the waste. Any valid model has to be tailored to local conditions. MSW is basically a management problem. A conceptual, dynamic management model is available which may be adapted to particular applications. Experimentation is required to test and improve the conceptual model which is available to interested parties.

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