Université de Montréal

Closing the Resource Loop : The Role of Urban Composting in Municipal Solid Waste Management

par

Teresa Alper

Institut d'urbanisme

Faculté de l'aménagement

Mémoire présenté à la Faculté des études supérieures
en vue de l'obtention du grade de
Maître en urbanisme, option Environnement et cadre de vie (M. Urb.)

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For CK

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LIST OF ABBREVIATIONS

AAFC	Agriculture & Agri-Food Canada
BAPE	Bureau d'audiences publiques sur l'environnement
BNQ	Bureau de normalisation du Québec
CCC	Canadian Composting Council
CCME	Canadian Council of Ministers of the Environment
CDRL	Conseil de développement régional de Laval
CPTAQ	Commission de protection du territoire agricole du Québec
ICI	Industrial, commercial and institutional
ISHS	International Society for Horticultural Science
LRQ	Lois refondues du Québec
MAPAQ	Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec
MEF	Ministère de l'Environnement et de la Faune

Summary

The pertinent environmental, social and economic factors related to the development of sustainable solid waste management systems are highlighted within a discussion of the concept of urban sustainability. Particular attention is given to the recovery and transformation of the organic fraction of the municipal solid waste stream into a secondary resource, compost. It is hypothesized that the long-term success in achieving future (organic) waste reduction targets depends upon the establishment of links between municipal composting programs and the agricultural sector. It is posited that closing a resource, or nutrient, loop can be achieved by altering the linear flow of organic materials through the urban economy by directing municipally generated compost to a peri-urban agricultural zone. The regulatory and political framework underlying waste management activities, in general and municipal composting activities, in particular, is reviewed with reference to developments in other jurisdictions. A case study is conducted of a municipal regional county that has both urban and agricultural functions throughout its territory. The conclusions drawn from the case study indicate that an expanded municipal composting program could effectively supply the soil amendment requirements of the region's agricultural sector. The development of sustainable agricultural and municipal waste management practices for the region would require multistakeholder consultations. Recommendations for future research that would further the acceptance of municipal composting programs are suggested.

Résumé

L'étalement urbain dans le monde occidental et l'urbanisation accélérée dans les pays en voie de développement font en sorte qu'à l'aube du nouveau millenaire près de 50% de la population mondiale vivra dans les centres urbains. De plus, les espaces autrefois disponibles (à prix abordable) pour l'enfouissement des déchets subissent des pressions pour le développement et de ce fait, chaque année des millions d'hectares de sols arables sont soustraits de la production agricole et ceux qui restent subissent de fortes pressions résultant dans l'appauvrissement de la ressource non-renouvelable qu'est la terre.

La gestion intégrée des déchets solides est devenue un enjeu stratégique dans la gestion municipale surtout dans un contexte de développement urbain viable. Malgré les efforts au cours de la dernière décennie, force est de constater que l'objectif de la réduction par 50% des déchets à la source ne serait pas réalisé. Le recyclage est plus économique que l'enfouissement en décharge ou l'incinération pour la plupart des matériaux et il constitue un moyen direct par lequel chaque ménage peut contribuer quotidiennement à réduire au son impact négatif sur l'environnement. Mais à lui seul, le recyclage n'assure en rien une réduction des déchets destinés à l'élimination. Les pratiques de compostage offrent un moyen de diminuer, de façon significative, les quantités de déchets solides destinés à l'élimination car on estime que jusqu'à 60% de ces derniers sont compostables et celles-ci permettent de valoriser des ressources dans le contexte de la gestion intégrée des déchets urbains. En fait, afin de réaliser les objectifs de réduction à la

source des déchets destinés à l'enfouissement, de plus en plus de décideurs municipaux nord-américains optent pour l'instauration des programmes de compostage. La planification de ces programmes doit tenir compte des aspects techniques ainsi que des besoins et des attentes de chaque communauté locale afin d'assurer que le niveau de succès souhaité soit atteint. Le recyclage des matières *organiques* est typiquement associé au milieu rural et l'acceptation des pratiques de compostage en milieu urbain constitue un défi important dépendant, en grande partie, de stratégies fiables qui faciliteraient l'adoption de ces dernières. De plus, une gestion efficace et controlée des matières s'avère essentielle afin d'assurer l'intégrité de la santé et de la sécurité de tous les intervenants oeuvrant dans la collecte et la transformation de ces dernières ainsi que du milieu récepteur. Toute implantation ou expansion éventuelle des programmes de compostage municipal soulève forcément la question sur l'usage ultérieur du produit. La valorisation des déchets organiques dans une ressource secondaire, le compost, peut contribuer à l'aménagement des espaces verts municipaux, à la réhabilitation de sites contaminés ou dégradés, ainsi qu'aux pratiques écologiques dans la gestion des sols agricoles. Le secteur agricole constitue un marché potentiel pour le compost, surtout pour les applications de surface et pour le remplacement de la tourbe dans l'industrie horticole pourvu que le compost acheminé soit du plus haute qualité.

Est-il réaliste d'envisager que les résidus urbains compostés soient dirigés vers le secteur agricole? Le sujet de recherche se réfère à cette question et nous examinons le rôle que peuvent jouer les pratiques de compostage des déchets organiques urbains par rapport au développement de marchés à l'intérieur d'une zone agricole péri-urbaine. Le contexte politico-légal québécois étant actuellement favorable à l'harmonisation des activités agricoles ainsi que municipales, notre travail explore donc la possibilité d'établir des liens entre le milieu urbain et une zone agricole par le biais de la valorisation des résidus organiques municipaux.

La problématique de l'importance stratégique de la gestion des déchets dans le contexte du développement urbain viable figure au chapitre 1. Nous y examinons les aspects environnemental, social et économique qui influent sur les politiques et les comportements humains dont dépendent le progrès vers le développement durable. Au chapitre 2 nous présentons les différentes composantes des systèmes de gestion des déchets solides municipaux dans les pays industrialisés tout en nous référant aux expériences révélatrices du Tiers Monde. Les politiques et les programmes gouvernementaux relatifs au sujet de la gestion des matières résiduelles figurent au chapitre 3, où il est auusi question d'examiner les normes qui dictent la production et l'usage du compost. Une étude de cas sur Laval figure au chapitre 4. Le sujet de recherche pour le mémoire a été choisi lors d'un stage effectué à la Ville de Laval dans le cadre d'une activité à l'intérieur du programme d'urbanisme. Notre mandat à la Ville de Laval fut de préparer un rapport sur le marché local pour le compost municipal. Au chapitre 4 nous retraçons l'histoire agricole de l'île Jésus jusqu'au contexte actuel et nous analysons le programme de la collecte à trois voies à la Ville de Laval. De plus, nous examinons le rôle que peuvent jouer la collecte et la transformation des résidus organiques par le biais de ce programme municipal pour valoriser cette ressource secondaire auprès du secteur agricole local. Lors du stage nous avons développé un sondage à l'intention des agriculteurs de la région pour déterminer le niveau d'intérêt face à l'usage du compost municipal. Il avait été convenu que les résultats du sondage seraient disponibles pour les fins d'analyse pour notre mémoire. Malgré les bonnes intentions de tous ceux qui étaient impliqués, le sondage n'a pas été distribué et il nous fallait trouver d'autres sources de données. Une revue de la litérature a révélé que peu de recherche existe sur les aspects urbanistiques du recyclage des matières organiques municipales, la plupart de l'information remontant au domaine de la gestion des déchets et à la science horticole. Malgré les difficultés méthodologiques rencontrées en cours de route, nous avons pu conclure qu'il serait possible de créer de liens stratégiques à Laval entre les secteurs agricole et municipal du point de vue technique et opérationnel. Une telle initiative nécessiterait la tenue de pourparlers ouvert et accessible, impliquant tous les intervenants des différents milieux dans la mesure où les questions reliées au développement durable figurent au premier plan. C'est dans ce contexte que la notion de fermer une boucle de ressource est abordée au chapitre 5, où il est aussi question d'examiner les composantes nécessaires au développement d'une stratégie municipale pour gérer les matières organiques tout en considérant l'établissement de liens entre les milieux urbain et rural. Nous terminons avec une série de recommendations pour la recherche ultérieure.

Introduction

Sustainable development is a concept that has developed during the last fifty years, since the end of the Second World War. This notion emerged as a result of the realization that social inequity and environmental degradation were inextricably linked to issues of economic and human development, especially in countries of the Third World. In addition to its initial environmental focus (Milbraith, 1989; Turner, Pearce & Bateman, 1993), the debate on sustainable development has broadened to include other elements such as demographics (Rowley & Holmberg, 1992; D.J. McLaren, 1996), design (Todd et Todd, 1994; Van de Ryn et Cowan, 1996), economics (M. Jacobs, 1991), politics (Cohen, 1996; Ducci, 1996; Selman, 1998), human behaviour (Low & Heinen, 1993; Stern, Dietz & Guagnano, 1995), sociology (Boothroyd, 1995) and urbanism (Hardoy, Mitlin & Satterthwaite, 1992; Stren, White & Whitney, 1992; Chowdhury & Furedy, 1994). Since each of these elements is also subject to its own spectrum of interpretations, it comes as no surprise that, by 1992, there were 70 definitions of the term sustainability (Holmberg and Sandbrook, 1992).

The International Union for the Conservation of Nature identified a series of objectives for the realization of sustainable development. They include: integrating conservation and development, satisfying the most basic human needs, achieving equity and social justice, providing for cultural diversity, and maintaining ecological integrity (Jacobs & Monroe, 1987). At the Earth Summit, held at Rio de Janeiro in 1992, the principles of sustainable development were officially adopted and the signatory countries committed themselves to implement actions for promoting sustainability. Numerous analytical tools, such as indicators and indices, are used to measure the progress made towards achieving sustainable development. By definition, an indicator simplifies the complex nature of reality by measuring and tracking one particular aspect of it; indices, which are derived by aggregating numerous indicators, measure the overall progress of achieving the objectives of a specific plan or policy (Hall, 1992, Parenteau, 1982). A "good" indicator of sustainable development must reflect an integration of economic, environmental and social considerations, and must be applicable to all sorts of communities (Maclaren, 1996).

The population of the developed world respresents only 25% of the total world's population (Brown, 1996), yet it consumes 85% of the planet's resources and produces proportional amounts of pollution and waste (D.J. McLaren, 1996). Even though the issue of waste doesn't have repercussions at a planetary scale, the development of policies on integrated waste management is often associated with the adoption of the principles of sustainable development (Ouellet, 1993). In fact, most Canadian municipal leaders have identified the management of municipal solid waste as a primary environmental concern in each of their respective communities (SCHL, 1995). Integrated solid waste management systems are based on the principles of waste reduction, recycling, reuse, transformation (into secondary resources) and safe disposal (BAPE, 1997; Murray, 1995). The implementation of these systems can contribute to the ecological objectives of sustainable development insofar as they reduce the overconsumption which is characteristic of the industrialized countries of the developed world. Since the late 1980's, many jurisdictions at the international, national, regional, provincial, and municipal levels have set objectives for reducing the total quantity of waste destined for disposal. The amount of waste generated per capita is considered a target by some (Maclaren, 1996) and a secondary environmental indicator by others (Jacobs, 1991). However, regardless of the terms employed, this figure has generally been adopted to represent the level of succes in reducing the amount of waste destined for landfill or incineration.

In adopting the *Politique de gestion intégrée des déchets* (1989), the Québec government set two principal objectives, the first of which was reducing, by 50%, the amount of solid waste destined for disposal by the year 2000 (Gouvernement du Québec, 1989). Unfortunately, ten years of effort have failed to produce the desired level of success, with overall waste reduction reaching only 11% by 1996. Following public consultations, this policy was replaced in 1998 by the *Plan d'action québécois sur la gestion des matières résiduelles 1998-2008*. This 10-year action plan seeks to reduce, by the year 2008, each type of solid waste by 60%, with public and private sectors sharing in an increased level of responsibility for materials throughout their lifecycle (Gouvernement du Québec, 1998b). The waste characterization studies that have been conducted in Québec indicate that degradable organic matter, such as yard trimmings and kitchen residues, accounts for approximately 20% of the *total* solid waste stream from the residential, and industrial, commerical and institutional (ICI) sectors, combined (Gouvernement du Québec, 1993a). Approximately 35% of all *municipal* solid waste is organic matter, meaning that an average garbage bag is comprised of over one-third of degradable materials (Léonard et al., 1989; Ville de Montréal, 1991). The recovery and composting of urban organic materials can provide an opportunity to significantly reduce the quantities of solid waste that are currently sent for disposal. Numerous examples of this type of practice exist, including the contribution that organic materials recovery and composting make to the informal economy of numerous Third World cities (Chowdury et Furedy, 1994; Grégoire, 1997) within the context of urban agriculture (Gardner, 1997; Smit et Nasr, 1992; Stren, 1992). Municipally generated compost can also function in the reclamation of contaminated or degraded soils, or "brownfields" (Schonberner, 1998). If the compost derived from urban organic materials is viewed as a secondary resource, then municipal composting programs can contribute to ecological soil management practices in both the agricultural and municipal sectors (CQVB, 1997; Gardner, 1997), provided that the quality and availability of this type of soil amendment is assured. Since the beginning of the 1990's, the use of compost derived from municipal organic materials has actually contributed to lowering the input of synthetic pesticides and fertilizers in certain agricultural productions in California (CIWMB, 1997).

During our course of study at the Institut d'urbanisme, we undertook a short-term practicum at the City of Laval, and were mandated to prepare a report on the marketability of municipal compost produced from the 3-stream waste collection program. This experience provided us with the opportunity to identify a topic of research for our master's thesis and we decided to research the extent to which it would be possible to close a resource, or nutrient, loop by directing municipally generated compost to the local agricultural sector. We developed a survey during the course of the "stage" to assess the interest amongst local farmers for purchasing this compost, and it was initially hoped that survey results would provide the necessary data for our thesis. Unfortunately circumstances dictated otherwise, and because the survey was not circulated, another source of data had to be found. An extensive litterature search revealed that very little research had been done on the issue of closing the resource loop from an urbanistic or urban management perspective, but that most of the relevant information could be found from the horticultural, scientific and waste management communities. We also attempted to develop an indicator that would be an extension of the generally accepted waste reduction target indicator, and that would reflect the degree to which compost, as a secondary resource, was being effectively directed to sustainable uses. However it became apparent that the development of such an indicator would represent a task was more suited to a doctoral dissertation, and thus was simply retained as a suggestion for further research. Despite the methodological difficulties encountered and the paucity of relevant information, we feel that it has been possible to demonstrate, through the use of data available for the Laval sector, that a resource loop can be effectively closed by linking a municipal composting program to the local agricultural sector.

Chapter 1 The Context of Urban Sustainable Development

1.1 Introduction

Urbanization is the second most important demographic trend of the late twentieth century (Brown and Jacobson, 1991). It is estimated that fifty-five per cent of the human population will be living in cities by 2015, accounting for about eighty per cent of the total population of industrialized countries and thirty-five to fifty percent of the population of less developed countries (UNDP, 1998). Rapid rates of urbanization and population growth in Africa, Asia and Latin America have led to "a profusion of sprawling, unplanned cities" which generally lack sufficient affordable housing and basic municipal services such as sewage and solid waste disposal (Brown & Jacobson, 1991). For the 600 million urban dwellers of these regions, poverty and environmental degradation are inextricably linked (Laquian, cited in Dahlan & Hainsworth, 1995) and the path towards urban sustainable development follows the "brown agenda", namely the satisfaction of the most basic human needs (Chowdury & Furedy, 1994). The availability of adequate services and infrastructure in industrialized countries means that populations there do not feel the immediate short-term effects of environmental degradation, thus concern about sustainable development focuses on the "green agenda", namely: global warming, thinning of the ozone layer, and depletion of non-renewable resources (Chowdhury & Furedy, 1994; Ducci, 1996).

Linking environmental and social concerns to urban economic development is a significant challenge to the field of urban planning (Chowdhury and Furedy, 1994; Lowe, 1991; Satterthwaite, 1992) and this, in turn, is dependent upon the ability to integrate human and social systems with biophysical processes (Parlange, 1998). Planning methods evolve in relation to the mores and priorities which define an era (Hall, 1992). The relatively new fields of environmental planning and ecological design incorporate certain changes to traditional planning procedures for managing and modifying the natural and built environments, respectively (Todd & Todd, 1994; Van der Ryn & Cowan, 1996). For example, suitability analysis is the stage in the environmental planning process that takes the specificity and limits of the surrounding milieu into account, thereby increasing the likelihood that the implementation of land-use plans will not compromise ecological integrity (McHarg, 1997; Roseland, 1994; Spirn, 1992). At the social level of concern, modifications to traditional "top-down" decision-making procedures, which encourage effective consultation and participation from various stakeholders, translate into a more supple and responsive process and facilitate the recognition of cultural and social diversity (Campbell, 1996; Taylor, 1992). The field of environmental economics proposes fundamental corrections to traditional models of economic activity as linear throughput systems by developing procedures for full-cost accounting of resource use, changes which could re-direct the focus of market-driven economies towards the promotion of equity (Jacobs, 1991; Turner et al.; 1993; Wackernagel & Rees, 1995). If implemented together, these changes could result, over time, in a radically altered set of relationships between man and the biosphere - and the paradigm shift towards sustainable development would be complete.

This scenario is ultimately dependent on the adoption of policies which are aimed at increasing the material and energy efficiency of economic activity, which is a prerequisite for reducing the "ecological footprint" (Rees, 1996) associated with the material standards and consumption levels characteristic of the developed world. One related concern for populations and decision-makers in cities of both the developed and less-developed countries is the issue of solid waste management (Heinen, 1995; Shikaze, 1991). Managing garbage has always been a part of the human experience and it currently represents a key component in the contemporary environmental debate between government, the private sector and the general public (Taylor & Todd, 1995):

> "Garbage is by definition close to home; people can see it, too often smell it, and are forced to deal with its consequences quite chronically. It therefore can't be ignored, unlike some other environmental issues such as the potential for global warming particularly through fossil-fuel consumption or of species' extinction through Amazonian deforestation - to cite two current examples. The issue presents iteslf on scales ranging from the local to widely regional..." (Heinen, 1995: 157)

1.2 Statement of research objective and hypothesis

Our research examines one component of integrated waste management in the developed world, namely the recycling of the organic fraction of the urban solid waste stream through composting programs. It is hypothesized that the long-term success in achieving future (organic) waste reduction targets depends upon linkages between municipal composting programs and the agricultural sector. Altering the linear flow of organic materials through the urban economy, by closing the nutrient loop, is studied in the context of the City of Laval, by determining the role that the municipal composting program can play in contributing to the needs of the island's agricultural zone. The following three sections of Chapter 1 examine certain environmental, social and economic factors that underlie this issue.

1.3 Environmental Considerations Related to Managing Municipal Organic Wastes

The growing global urban population is exerting pressure on agricultural soils and oceans which have already been depleted by rates of natural resource consumption and waste production that far exceed the absorptive capacity of their respective terrestrial and aquatic ecosystems (Brown & Jacobson, 1991; Chowdhury & Furedy, 1994; Rees, 1992). Cities are not totally self-reliant since they require the appropriation of biophysical resources from supporting regions (White & Whitney, 1992). Most cities of the industrialized world that draw heavily on external sources (for food, fuel and other products) appear to "float free, above their resource base", however the environmental consequences, or "ecological footprint" of this type of pattern is highly destructive (Rees, 1992). The reversal of this situation requires the development of sustainable strategies such as managing municipal organic waste and closing the nutrient loop that could be accomplished by directing recovered and composted organic residues to other uses. Unfortunately, closed nutrient loops are uncommon in most cities since much of the population has little contact with and experiential knowledge of the factors that impart its relevance and the development of such strategies will require a shift in attitude towards the issue of waste. The waste "crisis" of the developed world is primarily a reflection of the inability of existing infrastructures to keep up with the demand. The per capita rate of household waste production has declined in many OCDE countries (OCDE, 1997), however it is still two to three times higher than in developing countries where it is increasing annually at a rate one or two percent per higher than population growth (Furedy, 1995; UNDP, 1998). The probability that a resident of a developing country has access to municipal waste disposal services is 50-70 percent compared to 100 percent in developed countries, and significant environmental and health problems arise from inadequate or nonexistant infrastructure to manage these wastes (Kågeson, 1998; UNDP, 1998).

In traditional rural settlements, organic wastes are easily returned to the natural environment and, for over hundreds of years, the recycling of organic wastes from many Chinese cities has been integrated into local agricultural activity (Brady & Weil, 1996). However a shift away from the traditional use of organic amendments and composts over the past twenty years has led not only to increased crop yields but air and water pollution (Goldstein, 1998). The global industrialization of agriculture, characterized by intensive cultivation methods and a reliance on synthetic, inorganic fertilizers, has effectively disrupted the traditional nutrient loop, diminishing both the utility and function of organic wastes, resulting in environmental degradation

(Gardner, 1997). By adding organic matter in the form of compost to cultivated soils, physical properties such as soil structure, fertility, and water retention capacity are enhanced (Brady & Weil, 1996). Compost also provides a source of trace elements and has been recently found to promote the suppression of plant diseases (Hoitink *et al.*, 1997). Experience in Europe has shown that compost produced from mixed municipal solid wastes was not always suitable for use in agricultural markets due to the presence of heavy metals and other contaminants. The "new generation" of composting facilities in Germany and France, which process source-separated organic materials, now produce top quality compost that is safely utilized in plant nurseries, greenhouses, orchards and horticulture (de Bertoldi, 1998). Although the informal recycling of urban organic waste has been gaining acceptance within the context of urban and peri-urban agriculture in Asian and Latin American cities (Grégoire, 1997; Smit & Nasr, 1992), in most North American cities, organic wastes are mostly co-mingled with other garbage and buried in landfills, or incinerated. It is estimated that only 11% of total organic waste is composted in Canada and that of the 700,000 tons of compost produced annually, 42% is generated by municipalities through municipal composting programs (Ontario Centre for Environmental Technology Advancement, 1996). In Québec, a potentially useful secondary resource is being wasted since only 4% of urban organic wastes are currently being composted (Gouvernement du Québec, 1994; BAPE, 1997b) and a significant proportion of agricultural soils under (annual) monocultural production are depleted of their organic matter content (Sauvesty & Tabi, 1995).

In California, yard wastes and other organic residuals have been diverted, via composting programs, to vegetable and animal feed production since the late 1980's (Goldstein & Gray, 1999). In 1994, compost demonstration projects were initiated by the California Integrated Waste Management Board to promote the use of (municipal and household) yard trimmings in commercial agriculture (CIWMB, 1997), directing tons of materials to a market interested in adopting ecological production methods (Porter, 1999). The California Compost Quality Council has developed verification programs and strict controls on the quality of compost and composting programs to increase the production and appropriate use of compost in California (Cotton, 1999), thereby ensuring that the linkages between composters and farmers do not threaten environmental quality or public health. The problems of soil degradation and solid waste management can be effectively merged into a unified solution when the nutrient loop is closed and the function of organic matter is reinstated. It is time to act:

> "Further research is not needed in most cases: technologies to address most environmental problems exist; despite our knowledge, the gap between what is needed and what is being done is widening worldwide; this continued environmental degradation worldwide is the greatest threat to food security and socio-economic development" (Pimentel, 1998).

The following section of Chapter 1 examines some of the social factors that impinge on the adoption of conservation behaviour as a means for turning the tide on environmental degradation.

1.4 Social Considerations Related to Conservation Behaviour

Although the absolute amount of solid waste being sent to landfill in OECD countries has decreased slightly over the past two to three decades (OECD, 1997), many jurisdictions have had difficulty in reaching their waste reduction targets (BAPE, 1997a). The lack of success in reducing wastes at source indicates that fundamental behavioural changes required to reverse the trends characteristic of the consumer society have not yet occurred (Chevalier, 1995; Cope, 1995; Porter et al., 1995). The waste reduction targets, envisaged for the year 2002 in the Quebec government's recent 10-year plan for the management of solid wastes, are dependent upon significant changes occurring in citizen (and corporate) attitudes and behaviour towards the issue of waste (Gouvernement du Québec, 1998b). What are some of the elements that will enable this change to occur? The rest of this section reviews a few of the conclusions from research into the extrinsic and intrinsic factors which are thought to influence the development of environmentally responsible and socially conscious behaviour, in general, and the intention to engage in recycling and composting, in particular.

Seemingly benign choices made by one individual can exert significant impact on the environment and affect quality of life when multiplied millions of times by members of a collectivity.

> "The decision of the individual to live in the suburbs and commute to work in the center-city by car has negligible impact on resource consumption. Multiply the single individual by millions and you have the air pollution

> problems of New York City and Los Angeles." (Spirn, 1984, p. 230).

The solutions to many large-scale problems are found at local and individual levels of intervention and it has been found that cooperative efforts between public officials, the community and the private sector have achieved mutually desired and environmentally beneficial ends (Taylor, 1992).

> "Greater chances of success (occur) in neighbourhoods where residents already have a high level of civic interest and already feel involved to some extent in community objectives." (Taylor, 1992, p. 91.)

The nature of the decision-making process has a direct bearing on participation rates. Community support is essential for issues related to improving the quality of the local environment and to ensure a positive outcome for program implementation, and municipal decision makers must be able to achieve a balance between "needs of the local community with regional and national priorities" (Taylor, 1992). The extent to which individuals are willing to adopt conservation behaviour and alter their lifestyles and to consume less depends on a host of variables. It is believed that moral judgment processes affect an individual's attitudes toward environmental protection (Stern *et al.,* 1985). The decision to engage in the collective process to establish forms of sustainable development is a primary example of a moral choice that is dictated by a sense of responsibility towards future generations and not by short-term, individual, interests (M. Jacobs, 1991). The New Ecological Paradigm, which underlies this type of choice, embodies the beliefs that human survival depends on the health of the global environment (and not, for example, on human ingenuity), and that pollution and environmental degradation are morally wrong (Stern *et al.*, 1995). It has been found that individuals who undertake various actions aimed at correcting a particular environmental problem experience a sense of empowerment even when the direct outcome of those actions brings benefit to other, unknown persons or to the common good (Stern et al., 1986). However the truth is that most individuals do not willingly alter engrained behavioural patterns unless provided with strong incentives or reasons to do so (Cope, 1995; Heinen, 1995).

Recycling and composting provide a direct means by which individuals can contribute on a daily basis to reduce their negative impact on the environment (SCHL, 1995). The number of recycling and composting programs in OECD countries has grown over the past ten years (OECD, 1997) and although pro-environmental attitudes are polled in large segments of the North American population, participation rates in recycling and composting programs is less consistent with expressed views (Everett, 1997). It has been found that participation rates vary according to external factors directly controlled by residential recycling programs, such as market, coercive, convenience, and promotion strategies, or by instrinsic factors such as attitudes, beliefs, and demographics (Everett, 1997). Authors of a University of Guelph study report that favourable attitudes towards recycling and composting resulted when individuals perceived the relative advantages of these activities as being high and the complexity as being low; conditions which can be achieved by minimizing inconveniences and disseminating pertinent information, respectively (Taylor & Todd, 1995). Social pressures designed to encourage individual conservation behaviour (such as collectors who do not pick up wastes that are improperly disposed of and who leave warning notices along with the uncollected refuse) are important early in program development but may actually have adverse affects later on. The acceptance and implementation of successful recycling and composting programs are also influenced by economic realties, and this is the topic of the following section.

1.5 Economic Considerations Related to Solid Waste Management Systems

Traditional economic analysis has viewed the economy as being separate from the environment where flows of exchange value (capital and individual inputs) operate in a linear fashion (Turner *et al.*, 1993). The various repercussions on the environment (pollution, species extinction, etc.) of economic activity are thus considered external to the economy, hence the term "externalities" (Jacobs, 1991). This representation ignores the fact that the flows of energy and matter which support the economic exchange of goods and services are dependent upon the laws of thermodynamics which govern biophysical processes (Rees, 1992). Environmental economics is the branch of economics that emerged in the 1960's, during an era of growing environmental awareness (Norgaard, 1985). The economy and the environment are posited as having a reciprocal relationship, where the environment is affected by the consumption of resources and the production of wastes arising from economic activity, and the efficient working of the economy is impacted by the state of the environment (Turner *et al.*, 1993).

The landfilling and incineration of solid wastes are known to affect public health and welfare (by generating odours, noise, and traffic) and the environment (by contaminating groundwater, surface water and soil, and producting biogas, toxic ash and dust). Since these effects are generally considered to be external to waste management systems, they are rarely included in the calculation of the costs of solid waste collection, transportation, sorting, treatment or disposal (BAPE, 1997a; Gouvernement du Québec, 1993b; Murray, 1995). As a result, the average citizen or waste hauler in many jurisdictions, such as Québec, does not bear the full cost of solid waste management, reducing the incentive to adopt new practices such as composting. In 1996, the cost of waste disposal represented an average 4% of the budget of all Québec municipalities, a 76% increase since 1989 (BAPE, 1997a). As environmental controls are strengthened, the true costs of managing wastes should finally emerge, encouraging the implementation of measures to reduce the amount of wastes going to landfill sites or incinerators (Palmer et al., 1997).

As much as 60% of the municipal waste stream could be diverted by recycling organic wastes, of which 35% is comprised of food and garden waste (GRAIGE, 1989; OECD, 1997) and other compostable materials such as soiled paper and cardboard (Ville de Laval, 1998c). Dry, recyclable wastes (aluminum, glass and other papers) account for approximately 10% of the waste stream (OCDE, 1997). If composting and recycling programs are effectively implemented and maintained there is the potential to divert from landfill or incineration up to 70% of the total solid waste stream. The specific role that the recycling of organic wastes plays within the framework of the integrated waste management hierarchy is highlighted in Chapter 2.

Chapter 2 Municipal Waste Management and Composting

2.1 Introduction

In the ancient city of Athens, the initial solution for dealing with the problem of solid waste was, in a literal sense, to sidestep it:

> "Solid garbage was thrown into streets, where it attracted flies, rats and other vermin, and rotted into sludge that was so deep in some towns that stepping stones were provided for those who wished to cross the streets" (J. Donald Hughes, 1994, p. 193.)

Although it was subsequently decreed that wastes had to be transported and disposed of beyond the city walls (Murray, 1995), further lack of planning was borne by an ignorance of the nature and means of the vectors of disease. Historians estimate that during ancient and medieval periods, the deaths of hundreds of millions of people from the plague throughout Asia, Europe and the Mediterranean region were due, in part, to problems arising from the (non) management of wastes. It was not until the mid-to-late 1800's that the mechanisms responsible for the transmission of infectious diseases were understood, and for the bubonic plague, fleas, infected by the bacterium *Y. pestis*, were identified as the primary vectors. Animal hosts (such dogs and rats) were the secondary vectors that transported the fleas; humans, in close contact with the animal hosts, were bitten by the fleas and infected by the bacterium, developing the highly contagious disease that led to widespread epidemics (World Book, 1995).

> "The lack of any plan for the management of solid wastes thus led to the epidemic of plague, the Black Death, that killed half of the fourteenth-century Europeans and caused many subsequent epidemics with high death tolls. It was not until the nineteenth century that public health control measures became a vital consideration to public officials, who began to realize that food wastes had to be collected and disposed of in a sanitary manner to control rodents and flies, the vectors of disease." (Tchobanoglous et al., 1993, p. 5)

2.2 Managing Wastes

At the beginning of the 1900's, waste collection and transportion to dumping, burying or burning grounds on the outskirts of towns and cities became the disposal methods of choice (Tchobanoglous et al., 1993). International agreements were reached in the 1950's requiring nations to report episodes of plague or cholera and to implement corrective and preventive measures in an effort to completely eliminate the risks of pandemics (World Book, 1995). Although numerous international conventions have been reached on controlling the transboundary movement, management and disposal of hazardous (but not nuclear) wastes, arrangements do not exist for other types of solid waste (UNCSD, 1996), enabling the exportation of solid wastes from countries facing waste disposal problems, such as the United States. The problems which underlie the generation of so much waste in the developed world are related to numerous factors (please refer to the discussion in Chapter 1), including inefficient methods of production. It is estimated that for every 100 kilograms of products currently manufactured in the United States, 3,200 kilograms of waste is created, and in order to reduce overall material consumption by 50 percent, efficiency would have to double and the throughput of materials would have to be reduced by up to 90 percent (Baird, 1997). Up until the 1980's, the level of municipal waste collection services made it "easier and easier for the public to throw things away" (Haight, 1991) and, for most of this century, a large proportion of urban waste was eliminated through the process of incineration (Murray, 1995). Waste management emerged as an important public issue, with demands for change coming from an environmentally-conscious public, once it was realized that siting dumps and facilities further afield from human settlements was not an altogether benign solution. With evidence that leachates were contaminating the surface and ground waters used for human consumption and crop irrigation, and that toxics transported by dusts and gases were accumulating in soils, concern grew over the improper or non-existant procedures for the storage and elimination of toxic wastes (Steingrabber, 1997; UNDP, 1998). Citizens mobilized against the siting of waste facilities in their localities - the not-in-my-backyard, or NIMBY, phenomenon (Turner et al., 1993). The remaining sections of Chapter 2 review the functional elements of standard and integrated waste management systems, with particular attention given to the organic fraction of the municipal solid waste stream.

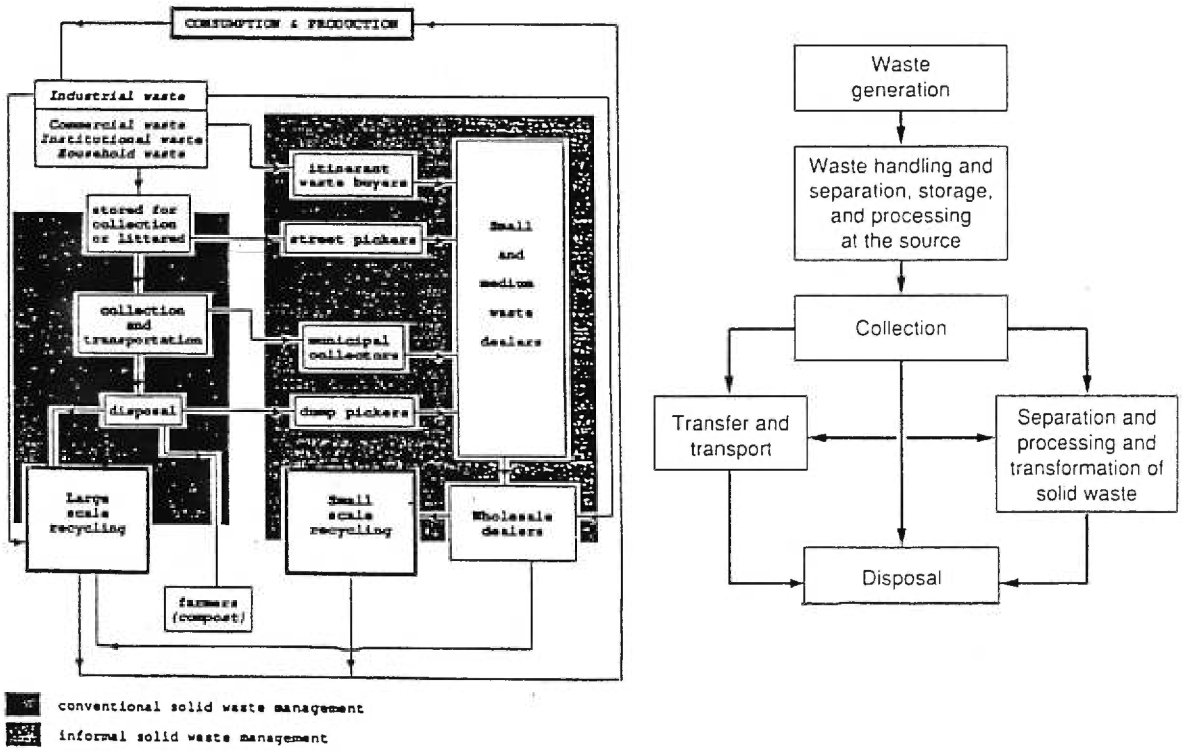
2.3 Waste Management Systems

Waste management systems of industrialzed countries are highly capital and labour intensive and are not considered appropriate for addressing the problems of solid waste management in developing countries. A comparative view of the functional elements of basic solid waste management systems in many cities of the developed world as well as informal solid waste management systems in cities of developing countries is illustrated below in Figure 2.1.

Figure 2.1 Comparison of solid waste management systems

Comparative view of
Conventional & informal
Solid waste management
In developing countries

Conventional
Solid waste management
in developed world



Sources: Huysman & Baud in Furedy (1995); Tchobanoglous et al. (1993)

In the developed world, formal waste management systems focus primarily on what occurs downstream from waste production and are planned from the perspective of improving the efficiency with which wastes are disposed of. In cities of the developing world, where waste collection (and other basic) services are minimal, waste dumps are sites where informal "wastepicking" and recycling activities, borne out of economic necessity and carried out in large part by low income residents or rural migrants, occur (Furedy, 1995).

> "The people who build their lives and homes out of other people's refuse are not viewed as eco-heroes by the societies they live in - no more than people who rummage in dustbins are in the West. They are, for the most part, regarded as little better than the trash they handle. They don't do this work because they want to, or because...they 'believe in recycling'. They do it because poverty and social inequality has given them a pitifully narrow range of options." (Baird, 1997, p. 8)

It has been estimated that these activities reduce the quantities of wastes that municipal authorities have to dispose of by up to 70% (Furedy, 1995). The waste problems of the West arise from excessive production and consumption, and the emergence of new strategies for dealing with wastes will depend on altering the definition of what constitutes a waste, and by viewing them as potential resources, where:

> "Each waste is systematically assessed and put through a recovery system before the disposal option is chosen" (Dumble & Whittaker, 1998).

The notion of closed resource loops will be discussed in Chapter 5, however that would not be possible without first examining each of the functional elements of waste management systems.

1. Waste identification

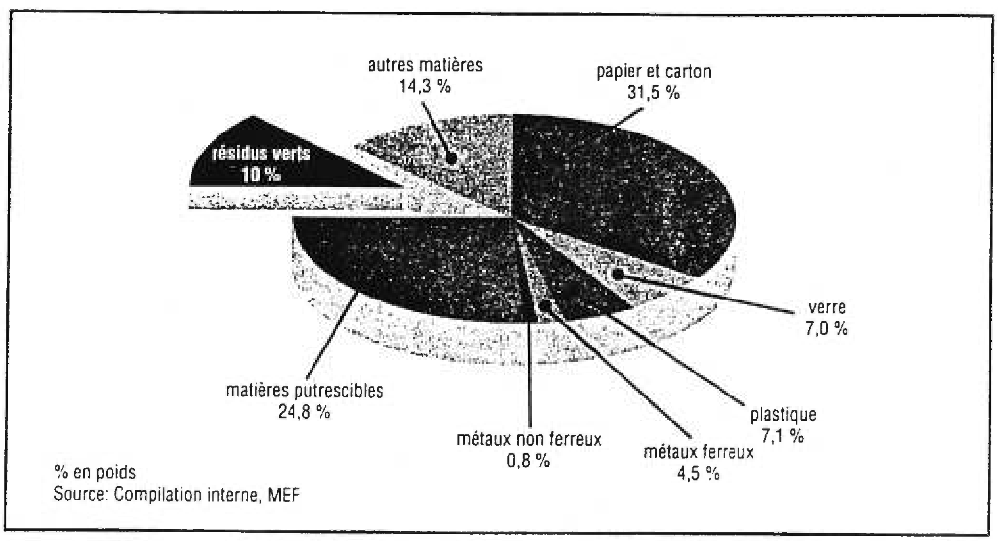
Rates at which wastes are generated are measured as amount (weight in kilograms) per capita or per household per year. The solid waste stream can be characterized according to the source, type and relative distribution of each component.

Sources of wastes are usually related to land use and zoning classifications: residential, commercial, institutional, contruction and demolition, municipal services, treatment plant sites, industrial, and agricultural.

Types of waste, or various components of the waste stream include: organic, inorganic, hazardous, and special wastes (such as bulky items).

Relative distribution of each type of waste is based on the percentage by weight of each component of the waste stream. The composition of municipal wastes in Québec is illustrated below in Figure 2.2.

Figure 2.2 The Composition of Municipal Waste in Québec



Organic wastes account for approximately 24% of the entire waste stream in Québec and up to 35% of the municipal solid waste stream.

2. Waste collection

100% of urban residents in the developed world have access to municipal waste services (OECD, 1997). Waste collection is defined as the gathering and transportation of wastes to locations where the collection vehicle is emptied (either a materials processing facility, a transfer station or a landfill disposal site). An estimated 50-70% of the costs of solid waste management systems goes to waste collection (Tchobanoglous et al., 1993).

3. Processing and transformation of solid wastes

Separation of wastes at source is usually associated with the recovery and recycling of "dry" components of the solid waste stream, such as aluminum, glass, paper, and plastics. The transformation of solid wastes can serve two purposes: either to reduce the volume and weight of waste requiring disposal or for the recovery, or valorisation, of conversion products (secondary resources such as compost) and energy (biogas).

4. Solid Waste Elimination

Either by landfilling or incineration, this is the final destination of the commingled wastes in developed countries that have not been separated at source, transformed or diverted to other uses.

2.4 The Organic Fraction of the Municipal Solid Waste Stream

Identification of organic residues

The type of organic materials routinely found in a municipality which are potentially suitable for composting include:

- food wastes
- yard wastes (grass clippings, leaves, brush)
- soiled paper and diapers
- pet feces

Sources of organic residues

Industries generate organic residues related to activities such as food production (farming, gardening) and processing. *Commercial* establishments such as grocery stores, hotels, restaurants, and public markets are another source of food waste and soiled paper. *Institutions* such as schools and hospitals also generate food wastes from cafeterias and yard waste from groundskeeping activities. All types of organic residues, albeit in varying quantities, are generated from *residential* buildings - single family and multifamily detached dwellings, low-, medium-and high-rise apartments. *Municipal activities* such as street cleaning, landscaping, catch basin cleaning, and maintenance of parks and other recreational areas is another source of organic residues.

Approximately 35% of the municipal solid waste stream in most North American municipalities is comprised of organic materials and in Québec the composition of the municipal solid waste stream (in 1996) has been estimated at (GRAIGE, 1989; Gouvernement du Québec, 1993a; 1998a):

• **Total Municipal solid waste:**	**2,033,000 tons**
• Total municipal organic residues:	810,000 tons (approx. 35% of total)
• Putrescible wastes:	589,000 tons (approx. 73% of organic and 28% of total)
• Yard wastes:	221,000 tons (approx. 32% of organic and 9% of total)

The composition of municipal solid waste varies between communities, regions, and also between countries. A similar pattern to Québec is found in the United States, where yard waste comprises approximately 11% of the total waste stream (Haug, 1993). It is interesting to note that food wastes account for 40% - 80% of the waste stream in middle and low income countries since most fruits and vegetables are neither packaged nor pre-trimmed and the amounts of the other components (yard waste, consumer items) are quite small (Tchobanoglous et al., 1993).

Collection of organic residues

In the majority of municipalities throughout Québec and North America, organic materials are commingled with other wastes. Leaf and yard waste is the organic material most commonly separated from the rest of the waste stream (Antler, 1998). As of 1991, leaf composting programs in 43 municipalities throughout Québec were responsible for the collection of nearly 16,000 tonnes of material, comprised mainly of grass, leaves and branches (Gouvernement du Québec, 1993a), which, after processing would produce roughly half that amount of compost or about 8,000 tons (Golueke, 1977). By 1995, the collection of organic materials had grown significantly since the amount of municipally generated compost had reached 16,000 tons (CDCQ, 1995). However, by 1997 only a handful of Québec municipalities (Montréal, Laval, Argenteuil and Deux-Montagnes) had initiated the collection of residential source-separated organic residues for the purposes of composting (Lachapelle, 1997; Ville de Montréal, 1996; Ville de Laval, 1998c).

One, Two and Three-stream Collection Programs

One-stream programs refer to the collection of non-separated or comingled waste; *two-stream* programs refer to the collection of source-separated dry recyclable materials (aluminum, glass, paper and plastics); and *three-stream* programs refer to the collection of source-separated dry recyclables and (wet) organic materials (yard wastes, kitchen residues, etc.). It currently costs between $30-$40 to landfill one ton of waste in Québec (Ville de Laval, 1998b), considered the lowest price in North America (Delisle & Bussières, 1998). Operating (transportation, fuel, labour) and capital (bins, specialized equipment and infrastructure) costs rise when additional waste streams are source-separated for the purposes of collection (Gouvernement du

Québec, 1998b; Recyc-Québec, 1998; Ville de Laval, 1998c). As long as landfilling and incineration costs remain low, an economic disincentive will exist that limits the expansion of source-separated recovery programs, thereby mitigating against the adoption of alternative strategies to these traditional waste disposal options (CDCQ, 1995; Gouvernement du Québec, 1998b; M.-H. Michaud, Provigo, 1998, personal communication; A. Giroux, Ville de Laval, 1999, personal communication). The collection of commingled waste is the norm in most municipalities, and as collection programs for dry (aluminum, glass, and paper) and wet (organics) recoverable wastes are added, costs rise. A comparison of cost for various options available for treating waste in Québec is presented below in Table I.

Table I Cost of Waste Treatment in Québec

Methods for eliminating or treating municipal solid wastes		**Cost per ton ($)**	
		Range	Average
Collection of non-separated waste	Commingled municipal solid waste	24-42	40
Collection of source-separated waste	[1]Transportation	50-200	125
	[2]Treatment at facility	50-60	55
Source-separated waste[1+2]			
• door-to-door collection	• Urban		195
	• Rural		270
• voluntary drop-off sites	• Urban		220
	• Rural		245
Incineration	2 incinerators in operation	28-100	75-80
Landfilling (78 active sites)	Treating < 20,000 tons/year	10-40	20
	Treating > 20,000 tons/year	10-40	28
Composting	• Windrow (non-reactor systems)	15-45	40
	• Compost facility (reactor syst.)	80-95	87

Source: adapted from CDCQ, 1995, p. 58

According to the tabulated data above, the estimated average cost of composting one ton of organic wastes, using non-reactor systems, is twice the cost of landfilling the waste. Prices have in fact doubled since the publication of these results so that it currently costs approximately between $35-40 to landfill a ton of waste in Québec (Ville de Laval, 1998c). The start-up costs associated with a 3-stream program which offers collection of source-separated regular domestic wastes, dry recyclables and organics is approximately $300,000 and the frequency at which wastes are collected has an influence on the cost of such services. The costs of a 3-stream program compared with a 2-stream program with collection once and twice a week appears below in Table II.

Table II Comparison Between 3-stream and 2-stream Collection for Laval

	3-stream	2-stream with biweekly collection	2-stream with weekly collection
	$ treating ton/year	$ treating ton/year	$ treating ton/year
Domestic waste (with diversion rates of 45% for organics and 15% for recylables)	$47/household	$72/household	$58/household
Recyclables	$20/ household	$20/household	$20/household
Organics	$41/household		
TOTAL	$108/household	$92/household	$78/household

Source: Ville de Laval, 1998c

Since collection and transportation costs for a 3-stream program are the same as for a weekly collection service, savings are generated when less material is sent to landfill. Costs are greater in the short term, by $15-30 per household, for source-separated three stream programs primarily as a result of the start-up costs related to the purchase of specialized equipment and the information campaign.

Alternative schemes for the collection of municipal organic residues

One of the problems with the current situation is that a different vehicle is used for the collection of each fraction of the waste stream. One truck picks up the waste destined for the landfill site, another picks up the dry recyclables and, where the programs exist, a third is used for the pick-up of organic residues. In Holland, the recovery of both regular and organic waste occurs simultaneously, using only one truck that has separate compartments for each type of residue (Ville de Montréal, 1995). To calculate the cost of transporting a ton of waste per unit of distance, communities can be divided into "wastesheds", using the distance from the centre of each wasteshed to a given waste-processing site (Levy, 1997). Traditional collection services in communities where a higher cost per unit distance exist could be supplanted by options less energy and cost-intensive, such as collection and treatment programs at the neighbourhood level. In fact, alternative schemes for the recovery of organic residues at the neighbourhood level, which are neither vehicle-dependent nor part of a supply chain for centralized processing facilities, have been envisaged by eco-city designers (Todd & Todd, 1994) and have been piloted in cities of the Third World (Furedy, 1992). On an even smaller scale, plans have been proposed where residents of apartment buildings separate organic refuse for in-vessel composting that occurs in their basement, thereby providing a growing medium for their own roof-top gardens (Lerner, 1997). In all cases, individual and collective responsibility towards managing urban organic residues must increase before the acceptability of local solutions can take hold. There is a debate over whether this can be best achieved through coercive or voluntary measures, with some arguing that satisfactory results cannot be achieved unless a monetary value is accorded to each element of the waste stream:

> "Les élus se fient trop à l'effort volontaire de chacun...Si on désire vraiment que le citoyen adhère à une politique de réduction des matières enfouissables, donnez une valeur monétaire aux déchets compostables et récupérables." (Giasson, 1998, p. 5).

Disposal of the organic residues

Since organic wastes are composed of putrescible, or degradable, materials and contain up to 60% water noxious gases can build up when they are landfilled and the efficiency of combustion is greatly reduced when they are incincerated (Gouvernement du Québec, 1998b; P.R. White et al., 1995). The negative environmental consequences associated with these traditional waste management options for organic residues can be avoided if this fraction is first separated out of the waste stream (Merillot, 1994; Ohr et al., 1998).

Transformation of organic residues

Two biological processes exist for treating organic residues: aerobic composting or anaerobic gasification (*it is the process of aerobic composting that is of direct interest to our research*). The selection of one or both options depends upon numerous factors including climate, geography, waste composition, infrastructure, finances, proximity to markets, etc. (Haug, 1993; Tchobanoglous et al., 1993; P.R. White et al., 1995). Furthermore, composting source-separated organic residues is more efficient than treating comingled wastes, leading to the production of higher quality compost (Haug, 1993; Ville de Laval, 1996).

2.5 Municipal Composting

Some definitions and terms[1]

Composting: is the process of controlled biological decomposition, and in the case of municipal solid waste management, composting transforms the organic component of the waste stream into a stabilized residue.

Mirobes: such as bacteria and fungi, are responsible for the composting of organic compounds that are used both as a source of energy and for cell growth.

Aerobic conditions: refers to the presence of oxygen. In the case of composting operations, aerobic conditions are maintained either by manual or mechanical agitation of compost piles or by forced air circulation. In the absence of oxygen, anaerobic conditions arise, leading to the production of offensive odours. A schematic representation of the biological process appears below in Figure 2.3.

Figure 2.3 Process of Aerobic Composting

Organic matter + Micro-organisms + Oxygen

⇓

Stabilized products (compost) + Carbon dioxide (CO_2) + Water + Heat

Source: Comité de santé environnementale, 1993, p. 104

[1] Source material for this section: R. T. Haug, *The Practical Handbook of Compost Engineering* (1993); C.G. Golueke, *Biological Reclamation of Solid Wastes* (1977); and D. Potvin & R. Cloutier, *Le compostage au Québec: problématique technique et inventaire des matériaux* (1989), Nature-Action, *Promotion du compostage domestique* (1995).

Pathogens: are harmful organisms that can be introduced along with many composting substrates. Human pathogens (faecal coliform bacteria; viruses) are present in disposable diapers and animal feces, and plant pathogens can be carried in diseased yard or garden wastes.

Decomposition stages: refer to the four stages in the composting process.

1. The thermophilic stage: large quantities of heat are released. Most pathogens are destroyed during this stage when temperatures reach between 55 to 60°C. In municipal composting facilities, conditions are monitored and controlled to ensure that this temperature range is maintained during a number of days (between 3 to 7 days, depending on the composting procedure employed).

2. The gaseous and liquid stage: water and gases are released during this stage when materials high in cellulose and lignin are metabolized.

3. The humification stage: end of the decomposition process *per se*, where microbes and organisms are no longer in the active stages of metabolism. The pile is composed of *humus*, a heterogenous material that includes compounds synthesized by microbes, and plant material resistant to further breakdown. The properties of *humus* confer many of the soil-amending properties attributed to compost: its biochemical instability contributes to cationic exchange capacity, and physical structure improves water retention capability.

4. The mineralization stage: the stage during which the compost matures and finally resembles black earth, leaving no recognizable materials.

Carbon-Nitrogen Ratio: The C/N ratio is a measure of the potential compostability of a given raw material or collection of raw materials. Microbes metabolize carbon for the production of energy and use nitrogen for growth. Optimal composting conditions arise when the proportion of carbonaceous to nitrogenous materials is 25-30:1, that is, for every available 25-30 parts of carbonaceous materials there is one part of nitrogenous material available.

Carbonaceous materials with high C/N ratios:

Paper		sawdust		woody materials		straw		leaves
200-500:1	>	100-500:1	>	100-150:1	>	70-150:1	>	30-60:1

Nitrogenous materials with low C/N ratios:

Animal feces		kitchen scraps		grass		garden residues
6-10:1	<	12-20:1	<	12-25:1	<	20-60:1

Municipal wastes tend to have high C/N ratios since the proportions of carbonaceous materials, such as newsprint, woody materials or leaves are relatively high. The addition of materials with lower C/N ratios, such as kitchen wastes, fresh grass clippings, or animal feces, helps to lower this ratio and produces more optimal conditions for composting.

Feedstock: refers to compostable materials.

Composting procedures (please refer to Appendix for more details): determined by the scale of intervention, the feedstock and numerous other factors. The most commonly used procedures, which are the least capital intensive, include non-aerated windrow and aerated static-pile composting. Guidelines and regulations have been developed for windrow composting, the method used in most municipal programs throughout Québec. Other options, such as reactor composting, requires significantly more capital investment, and is a method used more frequently in Europe (Haug, 1993).

In Europe and North America there is a growing interest in the practice of composting as a means for diverting more of the waste stream away from the disposal options of landfill and incineration. The implementation of municipal composting programs promotes environmental awareness (Bertolino and Lardenois, 1998), and compost can be used to remediate contaminated soils (Schonberner, 1998), control soil-borne pathogens (Hoitink & Krause, 1998), and rebuild depleted agricultural soils (Brady & Weil, 1996). Year round composting in northern climates presents certain difficulties however initiatives are currently underway with the objective of maximizing this potential (Tiberg, 1997; Ville de Laval, 1998c). Since climactic conditions affect the physical state of organic materials, it is difficult to separate partly decomposed or frozen materials from comingled wastes and then to produce high quality compost exempt of contaminants. In this section we only examine the case of the collection and biological processing of municipal organic residues, which constitutes roughly 25% of all organic wastes in the province (Gouvernement du Québec, 1998c). Strategies for dealing with the rest of the organic waste stream outside of the municipal waste collection loop, such as residues from the agricultural, fishery, forestry, industrial (food processing industry, for example) and parts of the commercial and institutional sectors, are not dealt with here. The success and cost-effectiveness of municipal composting programs will depend upon expanding the resource base, as it were, by collecting residues from local food processers (industry), retailers (commerce), and schools (institutions). Some of these options will be discussed in Chapter 5. The three scales at which the collection and composting of municipal organic residuals is currently conducted, and the elements related to each of these options, are compiled below in Table III.

Table III Composting at different scales of intervention

Element	Domestic Composting Program	Community Composting Program	Municipal Composting Program
Source of compostable materials	Single-family dwellings	Multi-family dwellings; local schools & small commercial establishments	Single & multi-family dwellings; institutions; commercial establishments; industry
Type of Compostable Materials	Grass, leaves, non-meat kitchen wastes, ground branches	Grass, leaves, non-meat kitchen wastes, ground branches, soiled paper	Grass, leaves, all kitchen wastes, ground branches, soiled paper & cardboard, animal feces
Type of collection	None	Limited to neighbourhood	Door-to-door
Expected participation rate	Moderate, since participants must invest considerable time & effort	Moderate, since participants must invest some time & effort	Elevated, since least amount of time & effort required
Negative environmental impact	Relatively low risk of offensive odours or undesirable insects (if poorly implemented)	Moderate risk of offensive odours or insects (if improperly implemented and due to possible lack of proper equipment to turn piles in winter)	Highest risk of offensive odours and liquid runoff (if improperly implemented); increased traffic, dust, noise around site
Costs	Least initial capital investment; no costs for transport or waste disposal	Moderate initial capital investment and operating costs	Highest initial capital cost and operating costs (tranportation & treatment of organic materials)
Quality of final product	Depends upon type of bin used, inputs and follow-up: usually low C/N ratio and low metal contamination	Depends upon inputs and follow-up, low C/N ratio and likely low metal contamination	Depends on technique, inputs and follow-up; highest risk of contamination if non-separated feedstock used; better control of C/N ratio
End Uses & Market Potential	Lowest: household & garden use	Low: possibly in community gardens & schools	Highest (when source-separated feedstocks are used): agriculture; municipal activities; soil remediation.

Source: Adapted from Gouvernement du Québec, 1993a, p. 30.

Energy (related to transportation) and labour costs for door-to-door pick-up services constitute a large percentage of the overall cost of waste management (Tchabonaglous, 1993). Despite this constraint, experience has shown that the successful implementation of large-scale municipal composting programs and production of quality compost depend upon the availability of services for the door-to-door collection of pre-sorted organic residuals (Ledgerwood, 1999). Some factors to be considered in the development of a door-to-door organics recovery program are highlighted below in Table IV.

Table IV Door-to-door collection of source-separated organic residuals*

Container used for residuals	Collection method		Composting method	Quality of final product**
none → (for yard waste only)	road-side → using vacuum hose	loose organic → materials	windrow formation and turning ↑	potentially good, however may be contaminated from oils and other pollutants on road surfaces
bags →	manual or → mechanical loading of bags	plastic bags → paper or → biodegradable bags	manual removal of bags	moderate, due to presence of plastic from bags or other contaminants included with residuals
bins →	mechanical loading →	loose organic → materials	windrow formation and turning	highest, due to absence of bag remnants

* Only source-separated organics residuals are considered; the reasons for not considering co-composting as a viable option were outlined in Chapter 2.
** The classification system for compost quality appears in Chapter 3.

There are over 250 centralized composting facilities in Canada, 52% of which are public and 48% of which are private operations, responsible for composting over 1.5 million tonnes of organics in 1996, with an estimated production of 600,000 tonnes of compost (Antler, 1998). In most of the municipally run centralized composting facilities, private entrepreneurs are hired to process the collected wastes (Gouvernement du Québec, 1994). At the neighbourhood level, non-profit and community organizations promote composting through activities such as the dissemination of information and training, vermicomposting projects in schools and collective composting in community gardens (Gouvernement du Québec, 1996; Nature-Action, 1995; Action RE-buts, 1997). The type of information required during the planning phase of the development of a municipal organics recovery program follows.

Information required for planning a municipal organics recovery program

- Waste characterization (source, type, quantity, etc.)
- Methods and costs related to the collection (Door-to-door pick-up, drop-off points, 3-stream collection vs. 2-stream collection, etc.) and composting (windrow, in-vessel, etc.) of materials
- Area required for the establishment of centralized (municipal or regional) composting facilities; of decentralized (community) operations; or of neighbourhood drop-off sites
- Information on the local and regional market for compost
- Choice of possible sites (locally or regionally, depending upon agreements between municipalities)
- Socio-economic profile of the population selected to participate in a program and identification of all the actors who could possibly be involved and/or impacted by the program under development

2.6 The Cost of Municipal Composting

The major operating costs of municipally run composting programs are related to the collection and transportation of wastes, with significant start-up costs for the establishment of environmentally sound installations (Gouvernement du Québec, 1994). Operating costs can be minimized through the adoption of simple and efficient technical procedures as well as through the use of equipment readily available in most municipal public works or sanitation departments (Gouvernement du Québec, 1994; Lachapelle, 1997). For each tonne of organic waste diverted away from landfill to composting, direct savings are achieved if tipping fees for organic materials at composting facilities are significantly lower than the area's landfill tip fees (Antler; 1998; Haight, 1991). In Québec, relatively low tipping fees actually discourage large-scale initiatives for composting. As a result, investment from the public to sector promote municipal composting programs creates higher (short-term) costs (Ville de Laval, 1998), a situation that would be expected to change if the cost of traditional waste disposal options were to rise (Palmer et al., 1997). The amount of compostable wastes collected in Québec has increased by almost 250% during a five-year period, going from 15,815 tonnes in 1991 to 375,500 tonnes in 1996 (Antler, 1998; Gouvernement du Québec, 1993a). The overall cost of managing municipal waste has increased by 76% in roughly the same period (BAPE, 1997a). In Quebec approximately 10% of compostable wastes (roughly 84,000 tonnes) is being diverted from landfill or incineration leaving 90% (or 840,000 tonnes) unrecovered (Gouvernement du Québec, 1998b; OCETA, 1996). The Québec government recently announced that by the year 2002 policies restricting the disposal of green wastes will be adopted and that a 60% organics recovery target for the municipal and ICI sectors is slated for the year 2008 (Gouvernement du Québec, 1998b). If, for the sake of argument, the rate of production of organic wastes remains the same, by the year 2000 roughly 504,000 tonnes will be recovered for composting, with an estimated production of approximately 300,000 tonnes of compost.

Most municipalities that have entered the composting arena first began by distributing subsidized domestic composters to their citizens, some then expanded their programs by designating (leaf) drop-off sites, and still others instituted door-to-door organics recovery programs in areas with established recyclables collection services (BAPE, 1997a). In fact, within each municipality, a mix of composting options that meets the needs of the local population, based on population density, land use, economic activity and other socio-economic factors, is required. The visionaries who work towards designing sustainable "eco-cities" through the integration of living and built systems, consider soil-building programs a component of urban restoration (Todd & Todd, 1994):

> "Were cities to begin a program of composting organic wastes the soil could be used for container and private gardening, neighborhood gardens, urban orchards, bioshelters, parks, and tree nurseries, all of which are integral to redeveloping communities and all of which are dependent on first-class soils...Composting on a block scale would be ideal...The compost thus produced can be sieved, bagged, and marketed." (Todd & Todd, 1994, p. 105).

The diversion of urban organic wastes away from the traditional waste stream has been initiated on a voluntary basis in most cases, although in a concerted effort to achieve 50% diversion by the year 2000, Nova Scotia became the first North American jurisdiction to completely ban organic residuals from the traditional waste stream (Friesen, 1999). In California, yard wastes and other organic residuals have been diverted, via composting programs, to vegetable and animal feed production since the late 1980's (Goldstein & Gray, 1999). The California Compost Quality Council has developed verification programs and strict controls on the quality of compost and composting programs to increase the production and appropriate use of compost in California (Cotton, 1999), thereby ensuring that the linkages between composters and farmers do not threaten environmental quality or public health. The composting option is likely to expand throughout Québec given that one of the government targets for the year 2008 is set at 60% diversion of the organic waste stream (to be reviewed in the next chapter). As municipally run composting programs develop throughout the province, the question of what happens to the thousands of tonnes of compost will be of some relevance for municipal managers. The usages of compost depend primarily upon the quality of the final product, which is determined by the procedures employed to produce it, the nature of the feedstocks (characteristics of the wastes), as well as the nature of the follow-up (Gouvernement du Québec, 1994). Questions of public health and security as well as environmental protection are raised when one considers the possibility of closing nutrient loops by directing municipally produced compost to agricultural, gardening or horticultural applications. The political and regulatory issues related to solid waste management and the practice of composting are outlined in Chapter 3.

Chapter 3 Legislation, Policies and Programs Governing Solid Waste Management and Related Issues in Québec

3.1 Introduction

During the 1970's, three major pieces of provincial legislation concerning agricultural practices, environmental protection, land use and urban planning were adopted in Québec. The development of this legislative framework occurred during an era when democratic ideals inspired decision-makers to:

> "(Find) ways in which citizens, through acting together, (could) manage their collective concerns, with respect to the sharing of space and time" (Healey, 1992, p. 145).

The legacy of advocay planning of the 1960's and 1970's was to challenge the traditional "top-down" approach of implementing planning decisions by exposing the fact that "planning is at its root deeply political. It must lead to an empowerment of all the people." (Heskin, 1980). The subsequent inclusion in the planning process of participatory and consultative procedures, to provide the public an opportunity to influence decisions (Warin, 1995), was in response to certain fundamental inequalitites that existed between participants. Corporate or industrial sectors possess the resources required for ensuring adequate representation, whereas disparate, underfunded and single-issue based non-profit, public and community groups or individuals do not:

> "What about imbalances of power? Developers hire expertise; neighborhood groups borrow it. Developers typically have economic resources; neighbors often have

> time, but not always the staying power to turn that time into real negotiating power." (Forester, 1987, p. 305).

The field of waste management has stakeholders in both private and public domains - nine of the sixty-nine active landfill sites in Québec are in private hands - and the nine privately controlled sites account for the elimination of 60% of all *landfilled* wastes in the province (Gouvernement du Québec, 1995d). There is a sense that the public interest can only be served if waste management activities are regulated by the public sector, so that the profit motive does not override concerns for environmental protection and social development:

> "It appears that, in effect, the wish is to reserve decision-making powers and control for the public sector, with the responsibility for activities and operations conferred either to private enterprise or to special municipally-controlled entities." (translated from original, in Delisle & Bussière, 1998, p. 19)

In 1989, the Québec government adopted an official policy on the integrated management of solid waste, aimed at: promoting voluntary waste reduction, reuse, and recovery (through recycling or composting), as alternatives to landfilling or incineration, and at instituting safer practices for the elimination of solid wastes (Gouvernement du Québec, 1989). By 1996, diversion programs had been successful in reducing the amount of waste destined for elimination by less than 15% of the total waste produced (as compared to the year 1989), far below the stated objective of 50% by the year 2000. In 1998, the government replaced its official policy on solid waste with a 29-point action plan outlining specific waste reduction targets for each of the waste-generating sectors in Québec and announcing a timetable for the adoption and implementation of future legislative controls

(Gouvernement du Québec, 1998b). The general legal and regulatory framework that encompasses the field of waste management in Québec, and the elements of the 29-point plan that relate to our research, will be presented in the following sections.

3.2 Laws and Regulations, Policies and Plans Governing Solid Waste Management in Québec

3.2.1 Laws and Regulations

The powers and responsibilities held by urban and rural municipal institutions are delegated by the provincial government and they are outlined in the City and Towns Act (L.R.Q., c.C-19) and in the Municipal Code of Québec (L.R.Q., c.C-27.1), respectively. All municipal by-laws pertaining to waste management and related issues must conform to the provisions contained in provincial regulations (De Connick, 1996) that may be found in the Environment Quality Act (L.R.Q., c.Q-2), an Act Respecting the Establishment and Enlargement of Certain Waste Elimination Sites as of 14 June 1993 (L.R.Q., c.E-13.1), an Act to Prohibit the Establishment or Enlargement of Certain Waste Elimination Sites as of December 1, 1995 (L.R.Q., c.I-14.1), the Act on Land Use and Urban Planning (L.R.Q., c.A-19.1), or the Act Respecting the Protection of Agricultural Lands and Activities (L.R.Q., c.P-41.1).

The Municipal Code (L.R.Q., c.C-27.1)

Adopted in 1870, the Municipal Code applies to the rural municipalities in Québec. Provisions dating back to that era, outlined the responsibilities of rural municipalities to adopt by-laws prohibiting garbage from being thrown on either the public or private domain for the purposes of protecting public health and safety and to preserve social peace. The notion of environmental protection *per se* was not officially recognized as a priority of civil society until one hundred years later, with the adoption of the Environment Quality Act of 1972 (Duplessis & Hétu, 1994). Article 678.0.1 of the act states that the regional county municipality has the power to provide various services including the removal or disposal of waste. The procedures related to the call for public tenders for contracts related to the execution of works, or the supply of equipment or materials, or the supply of services, are outlined in Article 935. Article 958 addresses the levying of taxes and licences.

The City and Towns Act (L.R.Q., c.C-19)

The City and Towns Act applies to urban municipalities and to every city or town municipality existing on 1 September 1979, plus the cities of Côte St. Luc and Dorval (Article 1). According to this law, municipal authorities have the power to define what constitutes a nuisance (Article 463). Article 413 outlines the obligations of individuals and of the municipality to collect, remove, and dispose of wastes, defined as "ashes, swill, offal, refuse, garbage, manure, dead animals, night-soil, and other unhealthy or offensive matter". Municipalities have the power to establish and operate a selective refuse collection system and to entrust any person with those functions; the council may pass a resolution requiring that every owner, tenant or occupant of an immoveable, separate from their household refuse those materials that may be recycled. The means of payment for these services can be either through taxes, which is the case in most Québec jurisdictions, or compensation. The municipality may, from a by-law, give or lend money to an investment fund intended to provide financial support to enterprises in a start-up or developmental phase, and the monies, not to exceed $500,000, must be administered by a non-profit organization established for that purpose and accredited by the Minister of Municipal Affairs.

The Act on Land Use and Urban Planning (L.R.Q., c.A-19.1)

This law confers to municipalities the power to manage the wastes that are generated, collected and transported within their territories and to designate sites for the installation of waste disposal sites. Master plans can include a description of the nature of infrastructure and equipment within the territory of a municipality (Article 8), however this law does not stipulate the conditions of operation of waste elimination facilities or services - these are found in the Environment Quality Act and the Regulation Regarding Solid Waste (L.R.Q., c.Q-2, R. 14). The next two sections outline some of those provisions.

The Environment Quality Act of Québec (L.R.Q., c.Q-2)

In Chapter 1 of the Environment Quality Act, waste management systems are defined as:

> "a combination of administrative and technical operations ensuring a rational method of removal, transport, storage, treatment, recycling and final deposit of waste and the moveable and immoveable property set aside for such purposes" (L.R.Q., c.Q-2)

Division VII of the Act deals with various aspects of the issue of waste management. The articles that are of particular interest appear in below in Table V.

Table V Articles from Division VII of the Environment Quality Act (L.R.Q., c. Q-2) pertaining to waste management

Article number	Provision
56	If a waste management system project contravenes a municipal by-law, an inquiry may be held to determine whether the said system should be exempt, wholly or in part, from the application of the municipal by-law.
61	The Minister of the Environment has the authority to order that a system of waste management or part of it be operated jointly by 2 or more municipalities.
70	The government may make regulations to: determine waste management methods; prescribe standards for the choice of sites for the installations used to operate a waste management system; determine the manner in which sites for elimination of waste must be operated and maintained; prescribe the terms and conditions and the minimum requirements relating to any contract between a municipality and any person responsible for the operation of a waste management system.

<u>The Bureau des audiences publiques sur l'environnement (BAPE)</u>

Division III of the Environment Quality Act contains provisions for the holding of public hearings on issues related to the quality of the environment. The Minister of the Environment has the power to confer this mandate to the Bureau (art. 6.3), requiring it to submit a report of its findings and of its analysis thereof.

The Regulation Respecting Solid Waste (L.R.Q., c. Q-2, r.14)

The Regulation Respecting Solid Waste outlines the specific provisions pertaining to the application of the Environment Quality Act. In the Regulation, various terms related to the management of solid wastes are defined such as composting, solid waste, lixiviat, incineration, etc.

Operation of a waste disposal site

Any municipality or individual may apply for a certificate or permit to establish or modify the operation of waste elimination or storage sites, and the related procedures are explained in Sections II and III of the Regulation, respectively. Zoning restrictions on the siting of landfill facilities (Section IV) require a minimum distance of at least 150 metres from flood plains, residential, commercial or mixed zones (Article 23), and municipal parks (Article 26), and at least 200 metres from any residence or educational institution, etc. (Article 27). Article 29, of Section IV, outlines the hydrogeological conditions that must prevail at a site destined for the operation of a solid waste elimination facility and the requirements for the installation of drainage and water collection systems. Articles 30 and 31 refer to the control of water pollution, with various issues related to security covered in Articles 32-60. For example, in Article 59, it is indicated that the operator of a site must see to the extermination of rats and vermin (through the use of poison, if necessary) during the period of active operation and three months following the definitive closure of a waste disposal site.

Composting

Most of the general provisions contained in the Regulation Respecting Solid Waste also pertain to the practice of composting, which is covered by three articles of

Section VII. Articles 80-82 refer to the standards for the siting of composting facilities, as well as to all other norms and the types of waste that may be accepted for treatment in composting facilities (toxic wastes are excluded).

The Collection and Transportation of Solid Wastes

Articles 104-110 in Section XII deal with the collection and transportation of solid wastes. Article 104 pertains to the frequency of waste collection, referring directly to the provisions included in the City and Towns Act (collection twice a week) and the Municipal Code (collection once a week). Articles 106 to 108 outline the manner in which wastes for collection are to be disposed of (type of container, weight, time of day, etc.).

Intermunicipal Waste Management Systems

Under Article 61 of the Environment Quality Act, the Minister can order that, failing an agreement, municipalities must share all or part of the costs related to an intermunicipal waste management system. Article 111, in Section XIII of the Regulation Respecting Solid Waste, outlines specific arrangements concerning cost sharing, namely the issues related to the initial investment as well as to operating and maintenance costs. Section XIV of the Regulation stipulates that there is a limit on the number of waste elimination facilities that may be established in each territory, with minimal distances between facilities calculated in relation to population size.

3.2.2 Policies

The Policy on Integrated Solid Waste Management (Politique de gestion intégrée des déchets solides)

This policy, adopted by the Québec government in 1989, was based on the 3RVE principles, that is: the 3R's of reduction, reuse and recycling; the fourth recovery option (such as composting) represented by the term "valorisation"; and to the safe elimination of wastes. Two clear objectives were outlined for all of the stakeholders involved in the management of solid wastes in Québec. The first goal reflected the waste management objective adopted by many other North American and European jurisdictions (that is, to reduce the quantity of solid waste destined for elimination by 50% by the year 2000) and, secondly, to improve the effectiveness and environmental worthiness of solid waste elimination procedures (Gouvernement du Québec, 1989). In 1989, there was very little information regarding the nature of the composition of the waste stream, with minimal coordination between the various stakeholders involved in solid waste management - two factors that made it very difficult to set realistic objectives:

> "En l'absence d'une connaissance précise de ces éléments (des quantités et des composantes), il est difficile, voire même impossible, de fixer des objectifs de performance environnementale dans le domaine de la gestion des déchets." (Gouvernement du Québec, 1989, p. 5)

3.2.3 Two Action Plans: 1991 and 1998

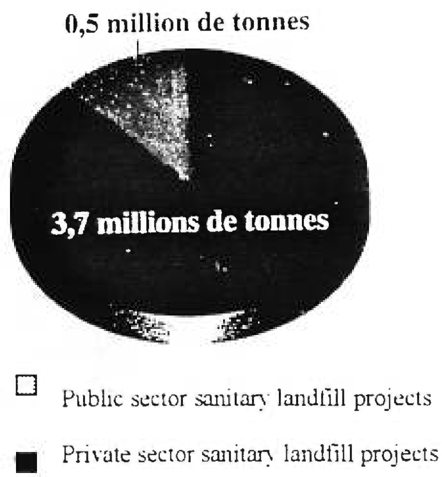
3.2.3.1 The Action Plan of 1991

In 1991, the Québec government instituted an action plan to evaluate and rehabiltate the landfill sites on its territory. This study revealed that none of the active landfill sites conformed to the provisions of the Regulation Regarding Solid Waste, in force since 1978. For example, watercourses (rivers, streams, etc.) were being contaminated at 83% of the sites where percolation waters were being collected and treated; consequently, fines were levied and waste disposal sites were closed (Gouvernement du Québec, 1995d). Further studies revealed the environmental and health hazards associated with landfill sites (Gouvernement du Québec, 1993b), and the government followed up with the adoption of two new pieces of legislation, which are briefly discussed in the following section.

An Act Respecting the Establishment and Enlargement of Certain Waste Elimination Sites (L.R.Q., c.E-13.1) and An Act to Prohibit the Establishment or Enlargement of Certain Waste Elimination Sites (L.R.Q., c.I-14.1)

Article 1 of the L.R.Q., c.E-13.1 prohibited the establishment or enlargement of sanitary landfill (or dry materials) disposal sites (after June 1993) unless the procedures for assessing and examining the environmental impacts of the project had been followed, and unless that person held a certificate issued by the Government for that purpose. The second Act (L.R.Q., c.I-14.1) introduced further restrictions to prohibit the establishment or enlargement of sanitary landfill sites, dry materials disposal sites and solid waste incinerators after December 1995 (Articles 1 and 3). In 1995, 97 requests were deposited for the establishment or enlargement of waste disposal sites - of the 40 requests regarding sanitary landfill sites, 17 were from the private sector, 12 of these were for the establishment of new facilities and five were requests for expansion (Gouvernement du Québec, 1995d). Over 90% of the landfilled waste in Québec is sent to sites controlled by the private sector - this is illustrated below in Figure 3.1.

Figure 3.1 Public vs. Private Control of Landfill Projects in Québec



Source: Adapted from Gouvernement du Québec, 1995 . p.19.

Public consultation on waste management

By 1994, it was clear that neither of the objectives outlined in the *Politique sur la gestion intégrée des déchets,* would be achieved, that is, the safe elimination of solid waste and, secondly, the reduction by 50% of waste destined for elimination by the year 2000 (since only 17% less waste was sent for disposal in 1994 compared to the amounts of 1988). In November 1995, the Minister of the Environment mandated the Bureau des audiences publiques sur l'environnement (the environmental public hearings board) to organize a commission of inquiry for the purposes of conducting public hearings into the issue of waste management in Québec, in an effort to aid in the development of a revised policy. The MEF identified underlying principles that would guide this new policy, including issues related to the right of citizens to participate and affect decisions; the specific and shared levels of responsibility of all the actors involved in waste management; the creation of viable partnerships; and the regionalization of waste management. The public consulation process took place during the year of 1996, hundreds of individuals went before the Commission to express their opinions and over four hundred written briefs were submitted. The Commission recommended that responsible and sustainable management of wastes shoudl be guided by the following principles (BAPE, 1997a):

- Sustainable lifestyles make rational use of resources.
- Environmental and public health can be protected by reducing the quantity of wastes destined for disposal by the 4R's.
- Producers are responsible for their products, consumers for the disposal thereof.
- Social equity guarantees the public's acceptance of either a waste management plan or facility.
- Municipalities are responsible for the implementation of waste management plans; MRCs or urban communities are responsible for their planning.
- The needs of a population must be met by waste management methods which are economically, environmentally and socially effective.

Composting

Composting is one of two possible solutions for the biological treatment of organic residues (the other being biogazification), as a means of avoiding the nuisances (odours, etc.), pollution (leachate) and health and security risks (biogas accumulation) normally associated with the landfilling of organic wastes (Haug, 1993; Gouvernement du Québec, 1993b; Tchobanoglous et al., 1993; P.R. White et al., 1995). In order to comply with more stringent environmental regulations for the operation of waste disposal facilities, significant capital investment is required for the installation of appropriate technologies to manage these effects (Auger, 1998).

These costs and problems can be reduced if organic residues are eliminated from the waste stream entirely and, during the hearings, a consensus appeared to emerge from amongst individual citizens, groups and companies for whom the development of the composting is the best waste management strategy (BAPE, 1997a). The Commission concluded that composting is an integral component of sustainable waste management, and its recommendations reflect the general consensus that emerged during the hearings regarding the need to lessen the restrictions on the establishment and operation of composting sites and of the usage of compost in agricultural and horticultural applications (Canadian Composting Council, 1996) while maintaining the necessary controls to ensure adequate levels of safety. The eleven points of *Recommendation 14: Regarding the Composting of Organic Matter and Green Residues* are presented below.

BAPE Recommendation #14: Regarding the Composting of Organic Matter and Green Residues

1. The government should prohibit the elimination of green residues as of the year 2000 and of compostable organic wastes by the year 2003;

2. The government should forsee a financing mechanism to cover part of the costs for the establishment of a municipal infrastructure for the recovery of green and organic wastes; such financing could be secured through the perception of a tax on waste disposal;

3. 3-stream waste collection systems maximize the recovery of organic and green residues and should be instituted;

4. Collecte Séléctive and the (proposed) society for waste management (SOVAL) should underwrite pilot projects in conjunction with municipalities or private entrepreneurs, for the purposes of determining the best practices related to the collection of compostable materials;

5. The government should insist that industries, commercial establishments and institutions that generate a certain level of organic and green residues enact recovery plans for these residues;

6. The government should modify the current regulations to facilitate the practice of composting and the safe usage of compost in agricultural and horticultural applications;

7. The government should adopt policies that encourage the acquisition and usage of compost in public works applications under its jurisdiction;

8. The (proposed) waste management society (SOVAL) should use funds from a tax on waste to encourage the establishment of composting facilities in collaboration with municipalities and private entrepreneurs; these funds could also be used to assist municipalities to finance the collection of organic and green residues;

9. The (proposed) waste management society should finance pilot projects to assist municipalities to identify the best practices of selective collection and the composting methods most appropriate to their region;

10. The (proposed) waste management society should promote research and development activities in conjunction with research facilities and the private sector in order to facilitate the emergence of more cost-effective techniques for the recovery of organic residues; it should also contribute to studies and research into identifying new markets and applications for the compost produced by the recovery of these residues;

11. The (proposed) waste management society should finance public information campaigns with the intention of raising the awareness of the importance of organic residue recovery and of promoting the use and market development of the resulting products.

3.2.3.2 Action Plan of 1998

Following the conclusion of the public hearings on waste management, the Québec government presented an action plan in 1998. The issue of composting is central to the *Plan d'action québécois sur la gestion des matières résiduelles 1998-2008,* as is apparent in the introductory section:

> "Degradable matter is principal source of contamination in waste elimination sites...The recovery of degradable residues reduces the polluting effect of waste elimination sites and the production of compost can contribute to the improvement of soil quality while reducing the usage of fertilizer and pesticides." (Translation from Gouvernement du Québec, 1998b)

The goal of recovering 60% of solid wastes from all sectors (municipal, industry, commerce and institutions) by the year 2008 can only be attained through concerted action between all stakeholders. Five principles, drawn from the Commission's report on waste management in Québec, underlie the action plan and are listed below.

Principles Underlying the 1998-2008 Action Plan on Solid Waste Management in Québec

- An integrated approach to waste management should be developed through the implementation of the 3RV-Es;
- Producers and distributors should assume more responsibility for their products throughout their entire life cycle;
- Citizens should have access to information and the opportunity to participate in the decision-making process;
- Public authorities should be given the responsiblility of developing municipal and regional waste management plans; and
- Effective partnerships should be formed in order to achieve common objectives.

The Actions

In order to translate these general principles into reality, specific short-term actions must be identified. This section examines some of the actions that are proposed in the plan, and the legislative or regulatory changes that will have to be implemented before these actions can be realized, are highlighted.

<u>*Action 1*</u>
Mandatory formulation of waste management plans by municipal regional counties, urban communities or their groupings.

<u>Action 2</u>
Entitlement of municipal regional counties and urban communities to monitor the origin of wastes disposed of on their territory.

<u>Action 3</u>
Implementation by municipal authorities of mechanisms for public consultation on the establishment and follow-up of waste management plans.

For Actions 1-3, amendments to the Act on Land Use and Urban Planning (L.R.Q., c.A-19.1) and to the Environment Quality Act (L.R.Q., c.Q-2) are required. To increase the cost-effectiveness and environmental performance of solid waste management systems, new obligations and powers must be conferred to urban communities and MRCs enabling them to plan for the development of appropriate infrastructure, including the authority to determine the quantity and origin of wastes destined for elimination on their territory.

<u>Action 4</u>
Implementation of monitoring committees by operators of waste elimination facilities.

<u>Action 5</u>
Implementation of an annual information and education program (of $2 million) in the area of waste recovery.

<u>Action 7</u>
Government financial support of close to $6 million over five years for launching and supporting organizations in the social economy that work in the field of solid waste recovery.

<u>Action 9</u>

Mandatory recovery of leaves and grass by municipalities for the purposes of transforming these residues, starting in the year 2002.

For Action 9, regulations banning the disposal of green residues are required. Effective collection services must also be developed throughout the territory, ensuring that citizens in all neighbourhoods have access to these programs and to the appropriate information.

<u>Action 10</u>

Implementation of an annual program ($3.5 million) to finance projects for the collection and composting of degradable residues.

<u>Action 20</u>

Adoption of revised norms for sanitary landfilling in order to ensure the protection of individuals and the environment.

<u>Action 22</u>

Obligation of the owners of waste disposal sites to manage a post-closure fund.

For Actions 10, 20 and 22, various regulations would be required to modernize the norms on waste disposal and incineration and to set up funding formulas for ensuring the coverage of costs related to the environmental management of sites for up to 30 years after their closure, respectively.

<u>Action 28</u>

Coordination by Recyc-Québec of all activities related to the recovery and transformation of residues to ensure that all efforts are well integrated and complementary.

Amendments to the Act on the Société québécoise de récupération et de recyclage (Recyc-Québec) are required.

<u>Action 29</u>

Biannual publication of a statement on waste management in Québec and a reevaluation of the orientation of the Plan d'action québecois every five years.

3.3 Mandatory Recycling and Banning Organic Residuals From The Waste Stream

There are a few jurisdictions in North America where legislation for the mandatory recycling of municipal waste has been adopted, including the state of California - in which the Integrated Waste Management Act of 1989 requires each city and county to comply with the officially adopted diversion rates and to prepare comprehensive plans for meeting those targets - and the state of New York - where the amount of materials reported as recycled increased by 43% during 1993, the first year of mandatory recycling (California Recycles, 1999; New York Senate, 1997). The State of Illinois adopted a ban on the landfilling of green wastes in 1990 (Illinois Environmental Protection Agency, 1997) and has set waste diversion and recovery rate targets of 25% and 28%, respectively for the year 2001 (Glenn, 1999). American states with legislation on mandatory recycling for local government include Maryland, New Jersey, Oregon, and Tennessee (Glenn, 1999).

The province of Prince Edward Island opted for mandatory residential source separation of all municipal solid waste in 1992, and, in 1994, a *regional* waste management program was implemented banning compostable materials (including food waste, nonreyclable paper, boxboard and yard trimmings) from landfill sites and with a diversion rate of 65% by 1997, the government was considering an extension of source separation throughout the entire province (Ledgerwood, 1999).

When the need arose to develop an integrated waste management strategy for the Halifax Regional Municipality, population 350,000, a group of 500 residents formed the Community Stakeholders Committee in 1994 - the CSC - and by 1999 a comprehensive plan had been worked out following a lengthy consensus-based decision-making procedure (Goldstein & Gray, 1999). The CSC strategy proposed that waste be separated into 4 streams (recyclables, compostables, trash and household hazardous waste) and that facilities, including composting plants, be constructed to treat each component of the waste stream (Goldstein & Gray, 1999). Despite opposition from municipal officials who balked at the estimated cost, citizens who had participated in the entire process were adamant that:

> "If they were not going to have curbside collection of organics or not to have a landfill ban on organics or not have it cover commercial organics, they would not support the landfill." (Goldstein & Gray, 1999, p. 40).

The province of Nova Scotia has since become the first jurisdiction in all of North America to ban the landfilling of all types of municipal organic residues throughout its territory, with all municipalities required to develop a composting infrastructure (Friesen, 1999; Gies, 1998). There are numerous examples throughout Europe either of mandatory source separation and composting of organics (Herbolzheimer & Colom, 1999), or of voluntary programs, and in all instances the best results have been achieved following a systematic approach that includes careful planning, adequate information and citizen participation (Lehto, 1999).

3.4 Safety issues related to composting

The implementation of Actions 9 and 10 (please refer to section 3.2.3.2) from Québec's solid waste management action plan will translate into the production of greater quantities of compost in the near future and to the exposure of workers to a new set of environmental variables. Specific agronomic and safety criteria must be respected if compost is to be acceptable for either agricultural or horticultural applications and to ensure the security of those involved in the production of compost, respectively. The main human health risk associated with large-scale municipal composting facilities is exposure of individuals (either workers or near-by residents), especially those who are hypersensitive to allergens, to large quantities of airborne endotoxins (noxious substances produced by certain types of bacteria present in compost piles), which could result in fatigue, nasal irritation, and other symptoms (Findall & Haight, 1991).

The purpose of developing consistent compost quality standards is to ensure that the usage of compost does not present any hazard to both the environment and any living organisms in contact with the product (P.R. White, et al., 1995). There are numerous criteria that can be considered when adopting a classification scheme, including: number of types or grades of compost; minimum processing requirements; heavy metal limits; restrictions on other characteristics; analytical methods and quality control procedures (P.R. White et al., 1995). The following section outlines some of the efforts that have been undertaken in Québec and Canada to develop compost quality standards.

3.4.1 Compost Standards

There are three organizations or interested bodies in Canada responsible for the development of standards and regulations for compost and composting.

- Agriculture and Agri-Food Canada implements the *Fertilizers Act and Regulations* which contains provisions on product safety, benefit claims and labeling that regulate the **sale** of compost in Canada
- The provincial and territorial governments, in conjunction with the Canadian Council of Ministers of the Environment, regulate and oversee the disposal and use of waste which includes the **production and use of compost**
- The Bureau de normalisation du Québec, that province's equivalent to the Canadian Standards Council, establishes **voluntary** industry standards (Canadian Composting Council, 1996).

Throughout Europe, Canada and the United States, various organizations have taken charge of defining and developing markets for waste-derived compost, including the Organic Reclamation and Composting Association (ORCA), the Canadian Composting Council, and the Solid Waste Composting Council (SWCC), respectively (P.R. White et al., 1995). The Canadian Council of Ministers of the Environment (CCME) Solid Waste Management Task Group coordinated a collaborative effort between various organizations across Canada to develop compost standards. The objective was to develop guidelines to minimize risk by protecting public health and environmental integrity and to standardize the criteria related to composting practices and quality of the final product. The development of safety regulations, at various levels of government, has been accompanied by the identification of voluntary quality standards. The guidelines are based on four criteria for product safety and quality: foreign matter content, compost maturity, and presence of pathogens and trace elements. The guidelines also reflect the principle that risk is a function of exposure, by establishing two grades of material: *Category A* compost is unrestricted and can be used in any application, such as agricultural lands, residential gardens, horticultural operations, the nursery industry, etc. *Category B* compost is a restricted grade where some control on usage may be necessary.

The Bureau de Normalisation du Québec

The BNQ is part of the Centre de recherche industrielle du Québec and has the mandate of acting in partnership with the public and private sectors to facilitate the improvement of the quality of products and services in Québec and to ensure their acceptance in external markets. The BNQ has developed voluntary standards for the compost industry based on general CCME guidelines. However there are three categories of compost (types AA, A and B), instead of two, providing a more precise categorization of biological, chemical and physical properties and introducing standardized sampling and analytical procedures (BNQ, 1997). The classification schemes are represented below in Table VI.

Table VI Classification of Compost

REGULATORY AGENCY	CATEGORY
BNQ	AA, A, B
CCME (provinces & territories)	A, B
AAFC	one category based on trace element limits of B

Source: CCC, 1996

Most standards relate to the biological, chemical and physical properties of the compost, focusing on the potential benefits and risks associated with the production and use of the product. The BNQ classification system rates Type B compost as the minimum standard for acceptable compost, with Types AA and A of higher quality. The distinguishing features between Type AA and Type A are foreign matter and trace element content and the CCME guidelines are based only on trace element concentrations. The AAFC recognizes only one class of compost based on the limits of trace elements for Category/Type B. The usages permitted for the different categories of compost appear below.

Permitted Usages for Composts

Category AA is permitted for applications leading to human or animal consumption, such as agriculture;

Category A can be used for all types of applications, although some restrictions may apply for agricultural usages, and in residential gardens, horticultural operations, nurseries, etc.;

Category B has restricted use, that is, it cannot be used in the above applications (is usually landfilled or used for site remediation)

Source: adapted from CCC, 1996.

A review of the safety standards as recognized by the BNQ appears below in Table VII.

Table VII Compost Quality Guidelines

	General provision	Type AA	Type A	Type B
PHYSICAL PROPERTIES				
• Water content	Maximum 60%			
• Total organic matter		50%	40%	30%
• Presence of foreign matter (metal, glass, plastic, rubber)	As % dry weight	≤ 0.01	≤ 0.5	≤ 1.5
	Maximum size in mm	12.5	12.5	25
CHEMICAL PROPERTIES				
• Maturity (a measure of the stability of the compost)	a) The C/N ratio must be ≤ 25 b) Biological oxygen demand ≤ 150 mg O_2/kg volatile solids c) Germination rates for watercress/radish seed >90% of control sample & growth rates ≤ 50%			
• Presence of trace elements (maximum concentrations mg/kg dry weight)	Cadmium	3.0	3.0	20
	Mercury	0.80	0.80	5
	Lead	150	150	500
	Zinc	500	500	1850
BIOLOGICAL PROPERTIES (presence of pathogens)				
• Fecal coliform	< 1000 MPN/g total dry solids (MPN: the most probable number; standard microbiological measure RE products for human or animal consumption)			
• Salmonella bacteria	∅ (i.e. there must be none present)			
IDENTIFICATION				
On bags, or in documents accompanying bulk shipments ** processed sewage; ash; synthetic or non-synthetic organic or inorganic or mineral fertilizer; bone; bone meal; agricultural, food processing, slaughterhouse, pulp & paper mill, yard, wood, fishery or municipal solid residues; blood; dried blood; blood meal; peat.	Generic list of ingredients used in the production of compost** and any substances added thereafter			Due to presence of trace elements, restrictions on usage must be indicated

(Source: Adapted from BNQ 0413-200/1997)

In addition to the establishment of reliable and manageable regulations, safe and effective composting practices also depend on the development of effective programs through which the actions of numerous actors must be coordinated (Canadian Composting Council, 1996). The following chapter presents the case of the City of Laval, which was successful in launching a pilot project on municipal composting that could serve as a model for similar communities in the rest of the province.

Chapter 4 Case Study of Laval

4.1 Introduction

The traditional distinctions between urban and rural economies have blurred over the past two to three generations, and there has been a generalized increase of non-agricultural activities in the rural sector as well as an extension of metropolitan regions into peri-urban areas (Bryant & Johnston, 1992; Richard, 1998; Tacoli, 1998). Much prime farmland is adjacent to urban areas, since characteristics which make land most suitable for agriculture - moderate climate, fertile topsoil with good drainage, sufficient water, and smooth land forms - also encourage urbanization (Science Council of Canada, 1972). It is estimated that the expansion of Canada's largest cities resulted in the transfer of over 62% of land with high agricultural capability to urban uses (Bryant, 1992). The Act to Protect Agricultural Lands (L.R.Q., c. P-41.1) and The Act on Land Use and Urban Planning (L.R.Q., c.A-19.1) were introducted in 1978 and 1979, respectively, in order to stem the dismemberment of the rural sector and to provide for orderly urban development (Archambault, 1987; Gibeau & Marcotte, 1982). This legislative framework has recently been modified to help create alliances between the urban and rural sectors (Gouvernement du Québec, 1998a). Farms occupy only three percent of Québec's territory with only a fraction of all production occuring on land of adequate agricultural capability (Pesant, 1998). Nevertheless, the agricultural sector in Québec generates billions of dollars in revenues and accounts for two-thirds of all the jobs in the primary sector (Gouvernement du Québec, 1998a). Official Québec government policy on *sustainable agriculture* is defined in terms of healthy and nutritious food production, the need for Québec farmers to be adequately prepared to compete in a global marketplace, and the protection of the environment and natural resources (Gouvernement du Québec, 1998a).

The first section of this chapter provides an overview of the state of agriculture in Laval - past, present and future - summarizes the process of urbanization and reviews certain elements of Laval's strategic plan. The chapter's second section presents the policies and practices of waste management in Laval, with an estimate of the potential for creating a sustainable link, through the practice of composting, between the agricultural and urban sectors.

4.2 Agricultural history

There is only one jurisdiction in Québec where the boundaries of a municipal regional county are identical to those of its principal municipality. That occurs in Laval, an archipelago of 77 islands and islets, with a total area of 245 km^2 situated northwest of the island of Montréal. The principal island of Île Jésus is encircled by the Rivière des Mille Îles, the Rivière des Prairies, and the Lac des Deux-Montagnes (Gouvernement du Québec, 1998b; Ville de Laval, 1998a). The island was first called Île Montmagny, then renamed Île Jésus in 1636 following the establishment of a seigneury that was ceded to the Jesuit order on condition that it be populated by French settlers (Lavallée, 1969). Around 1675, the seigneury was acquired by the first Bishop of New France, Mgr. François-Xavier Montmorency de Laval, and the land was subsequently granted to the Québec seminary (Ville de Laval, 1998a). It was not until 1701, and the signing of a peace treaty between the Iroquois and the French, that European colonization of the island was undertaken in earnest (Lavallée, 1969). Lots, bordering the rivers to the north and south, and in the form of long, narrow rectangles, were consigned to French immigrants who were responsible for clearing and cultivating the land, remitting a portion of their harvest as payment of tax (Lavallée, 1969). Land was ceded from the eastern tip to the western part of the island and by 1750 over half the area of the island (438 lots) had been relinquished by the seminary. Between 1735 and 1765, the population of Île Jésus tripled, reaching 2,379 inhabitants. By 1781, virtually all the land on the island had been ceded and the population had increased to approximately 4,600 individuals; by 1851, there were more than double that number, with over 10,000 permanent residents on Île Jésus (Dauphinais & Marien, 1981). By 1815, the network of roads around the island was complete, with a number of north-south routes ("montées") that bisected the territory and joined the two rivers (Dauphinais & Marien, 1981). The four original parishes - Saint-François-de-Sales, Sainte-Rose, Saint-Vincent-de-Paul and Saint-Martin - formed the boundaries of the first civic municipalities that were instituted following the abolition of the seigneurial system in 1854 (Bélanger, 1977; Dauphinais & Marien, 1981; Ville de Laval, 1998a). From the 17th to 19th centuries, and well into the middle of the 20th century, agriculture was the primary vocation of residents of Île Jésus (Lavallée, 1969). The establishment of farmers' markets in Montréal and the construction of the Viau and Lachapelle bridges, were factors that encouraged the gradual replacement of subsistence agriculture with commercial agricultural production on Île Jésus (Dauphinais & Marien, 1981). With the exception of the logging mill (Moulin du Crochet) owned by the seminary and situated at the future site of Laval-des-Rapides, the church establishment was able to exert its influence in blocking the introduction of industrial activity to the island (Dauphinais & Marien, 1981). The turn of the century ushered in the gradual urbanization of Île Jésus: the mill was sold, and land bordering the river was divided into lots for the construction of summer residents for Montrealers, and agricultural land elsewhere on the island was subdivided (Dauphinais & Marien, 1981; Ville de Laval, 1998a).

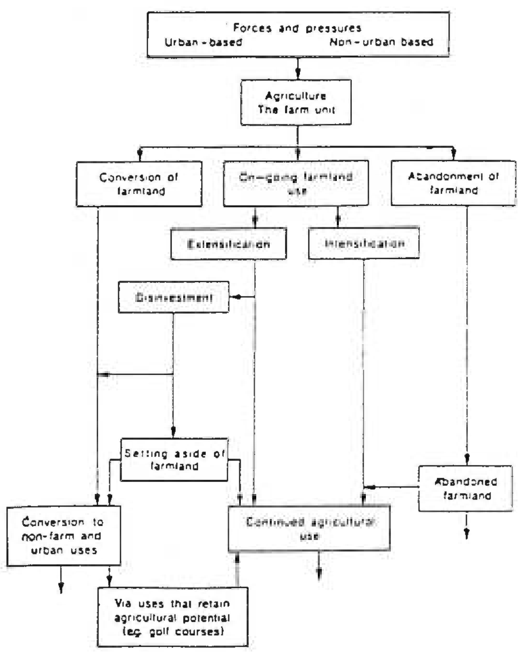
4.3 Rapid Urban Economic Development

The post Second World War boom in economic growth, massive public spending on roads and home ownership programs, and an increase in the private use of the automobile, were factors that fueled a migration of population to the suburbs (CPUQ, 1993). Municipalities on the island of Île Jésus expanded rapidly (Dauphinais & Marien, 1981; Ville de Laval, 1998a). The total population rose from 39,000 individuals in 1941 to approximately 25,000 in 1951, then doubled during each of the subsequent two decades to reach 110,000 and 200,000 individuals by 1961 and 1971, respectively (Archambault, 1987). The rural municipalities of Île Jésus developed relatively independently from one another (Dauphinais & Marcotte, 1981). However rapid urbanization throughout the island created competition for funds to develop and improve public services, in addition, intermunicipal conflicts arose regarding the duplication of certain equipment and administrative functions throughout the territory and related to differences in standards of assessment, etc. (Ville de Laval, 1968). Initially, three municipalities merged to form the City of Chomedy in 1961 (Ville de Laval, 1998a). In 1964, the provincial government established the Commission Sylvestre to these issues (Archambault, 1987) and in 1965, Bill 63 was adopted, which integrated the fourteen municipalities of Île Jésus into the City of Laval, the second largest urban community in the province of Québec (Lavoie & Denis, 1998). The Charter of the City of Laval confers particular powers to its municipal governement above and beyond those outlined in the Cities and Towns Act by dividing responsibilities between the Municipal council and an Executive committee (Ville de Laval, 1998a). Bill 63 also stipulated that an urban master plan had to be prepared within forty-eight months. The document that was produced in 1970 (Règlement L-2000) forecast that by the year 2000, all of the territory of Île Jesus would be developed and that the population would reach 1,000,000 people - a modernist perspective that decidedly broke with the island's agricultural past (Archambault, 1987). The evolution of land use in Laval will be discussed in the following section.

4.4 Evolution of Land Use in Laval

From 1952-1964, the percentage of land devoted to urban uses on Île Jésus increased from 3.2%- 21.7% (Lavallée, 1969) and from 1961-1976, the rate of residential housing construction soared, major economic and institutional infrastructures were established, and the island's industrial park was introduced (Archambault, 1987; Lavoie & Denis, 1998). Significant competition for land in developing ex-urban zones, such as Laval, led to speculation and the emergence of mixed land use patterns, so that traditional agricultural uses were juxtaposed alongside commercial, industrial and residential ones (Hénault, 1983; Richard, 1998). Unparalleled urban growth was occurring throughout all of Canada during this period, and the expansion of the country's largest cities resulted in the transfer of over 62% of land with high agricultural capability to urban uses (Bryant, 1992). The various urban and non-urban pressures that influence the removal of agricultural land from production are illustrated below in Figure 4.1.

Figure 4.1 Removal of agricultural land from agricultural production



Source: C. Bryant, 1992, p.29

According to the Canada Land Inventory, over 60% of the soil on Île Jésus belongs to Category I, II, or III, meaning that few restrictions apply as to the type of production possible and to the soil management practices required for rendering the land productive (Gibeau & Marcotte, 1982; Hénault, 1983). During the period of unbridled urban development, the transfer of prime agricultural land to urban uses on Île Jésus was accompanied by a 40% decrease in the proportion of land devoted to the commercial production of vegetables and a 56% decline in the number of dairy farms (Hénault, 1983). The government decree of 1979, which designated 47% of the territory of Île Jésus as an agricultural zone, also provided the municipality with a provisional plan, which allowed for the possibility of negotiating the inclusion or exclusion of land from the agricultural zone (Gibeau & Marcotte, 1982). The inclusion of 47% of the territory of Île Jésus into an agricultural zone created quite a stir in the Laval community - favourably rallying the agricultural and environmental sectors, albeit for different reasons - and generating a heated political debate during the municipal election campaign of 1981 (Archambault, 1987). Much of this debate centered on whether or not the central portion of the territory would be included in the agricultural zone since the 1970 urban plan had designated this sector as the future site for centralized commercial development (Archambault, 1987; Ville de Laval, 1968). The government mandated the Commission de protection du territoire agricole (CPTAQ) to produce an inventory of each agricultural zone, including Laval, in an effort to clarify the issues related to the use of agricultural lands (Gibeau & Marcotte, 1982; Robert Côté, Service de la documentation, CPTAQ, personal communication, 1999).

> "Le but de la présente étude vise essentiellement à dresser un bilan du zonage agricole et à répondre sommairement aux questions et attentes de la population, des MRC, des ministères ainsi que des organismes publics, para-publics et privés." (Gibeau & Marcotte, 1982, p.2)

The entire territory of Laval was subdivided into four sectors, and information was gleaned on the agronomic potential of the soils as well the proportions of the agricultural zone that were cleared, forested, or used for purposes other than agriculture (Gibeau & Marcotte, 1982). The report indicated that, as of 1982, 91% of the agricultural zone was being used for agricultural activities and that 74% of the non-agricultural zone was being used for urban purposes (Gibeau & Marcotte, 1982). The municipal and agricultural sectors succeeded in arriving at an agreement, regarding the extent of the agricultural zone, which was then submitted for approval by the Commission.

A dual status was conferred to Laval with the adoption of the Act on Land Use and Urban Planning (L.R.Q., c.A-19.1), designating it as a municipal regional county, or MRC, (Article 264). As such, the urban plan of 1970 was subsequently considered a master land use plan that had to be revised and then approved through a process of public consultation (Archambault, 1987; Dauphinais & Marien, 1981; Ville de Laval, 1998a). Each MRC and municipality throughout the province had to develop land use plans and planning regulations, respectively, however the provisions of the Act on Land Use and Urban Planning cannot control urban sprawl, which was only marginally kept in check by the Act on the Protection of Agricultural Lands:

> "La Loi sur la protection du territoire agricole a un caractère sectoriel...S'il est vrai que, lors de sa mise en application, le zonage agricole visait le contrôle du développement anarchique et de l'étalement urbain, les résultats sont loin d'être convaincants." (Fahey, 1992).

The specific presssures encountered by farmers whose lands are in close proximity to areas of urban development include increased property taxes, higher production costs, complaints from non-farm neighbours, etc. (Bryant & Johnston, 1992). These are factors that influenced many farmers in Laval throughout the 1970's and 1980's to either abandon their farms or to sell them at the first possible opportunity (Archambault, 1987). Concerns such as these were raised by the representatives of the agricultural community who participated in the public hearings on the revision of Laval's master plan, and it was generally felt that this sector of the Laval economy was under threat and needed greater protection and recognition:

> "Des espaces (verts) pourraient être aménagés comme zone tampon entre la zone agricole et la zone urbaine" (Ville de Laval, 1984, cited in Archambault, 1987).
>
> "Pourquoi ne pas la considérer comme une PME ou comme une industrie d'un parc industriel" (idem).

It is apparent that some of these suggestions were integrated into the stated objectives of the master land use plan of 1984 to: improve the quality of life; consolidate and revitalize the existing nodes of development; and recognize the importance of the agricultural zone (Archambault, 1987; Ville de Laval, 1984). Whereas agricultural activity had been perceived as an impediment to urban development throughout the 1960's and 1970's, the revised plan reflected the view that agriculture had as much of a role to play in the economic development of Laval as did the commercial and industrial sectors (Ville de Laval, 1984).

In general, most decisions by the Commission granting the exclusion of land from the agricultural zone are related to requests by municipalities for the enlargement of the urban perimeter (CPTAQ, 1994). Municipal and agricultural sectors had often been pitted against each other throughout the 1980's and 1990's as urban sprawl continued to exert pressure on farmlands, engendering numerous complaints (regarding nuisances such as dust, noise, and odours) and requests for inclusion or exclusion from the agricultural zone (CPTAQ, 1998). Recent legislative changes clarify certain procedures and are aimed at reducing friction between the two sectors. Some of the amendments include (SOQUIJ, 1997):

1. Requests for the introduction of non-farm activities within an agricultural zone will only be considered if accompanied by proof that there is no other land available within the limits of the municipality, but outside of the agricultural zone.
2. Requests for the exclusion of land from the agricultural zone (ususally for the extension of the urban perimeter) may only be presented either by an MRC or by a local municipality with the support of its MRC.
3. Municipal authorities are responsible for implementing controls on land use for the purpose of respecting the priority of farm-uses in the agricultural zone and for ensuring the integrity of the permanent nature of the agricultural zone.

To be in conformity with these legislative changes, the City of Laval introduced new regulations which include definitions of agricultural usage, and details on the procedure for the authorization of siting buildings within the agricultural zone, etc. (Ville de Laval, 1997).

4.5 The 1995 Strategic Plan for the City of Laval

In 1994, the Regional Development Council of Laval (CDRL) was mandated to develop a strategic plan for the City of Laval (CDRL, 1995). Informed consensus building is a critical component of strategy formation in public organizations (Nutt & Backoff, 1992). Consultation with various stakeholders was the first of the three steps in the process of defining the challenges specific to Laval, followed by the identification of the axes and perspectives for development, and, lastly, by the formulation of an action plan (CDRL, 1995). Difficulties normally encountered during broad-based consultations were minimized because of Laval's unique status as a city/MRC, which facilitated the integration of local priorities and the establishment of a common outlook. A consensus on the strategic importance of adhering to the principles of sustainable development was reached by the four hundred representatives who participated in twenty sectoral and intersectoral consultative sessions (CDRL, 1995).

> "Laval est appelée à jouer un rôle de plus en plus déterminant au niveau national et international si elle relève le défi qui se présente à elle: être la première ville-région du Québec à se doter d'une stratégie de développement durable[2]. Laval doit se doter d'orientations et de mesures d'intervention qui lui permettront d'exceller notamment dans les domaines du développement social et culturel, de l'environnement, du développement économique, des transports et de l'organisation publique et communautaire." (CDRL, 1995, p.2)

Nine priority sectors were identified in the strategic plan and the development of specific action programs for each of the nine target areas was to be assured through the involvement of various public, para-public, private and community organizations

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[2]Text underlined by the publication's author

(CDRL, 1995). Laval Technopole, a non-profit economic development agency financed in part by the City of Laval, was inaugurated in 1995. It has a 20-member board of directors comprised of representatives from the region's numerous economic sectors, two City councillors, and a member of the Laval Chamber of Commerce and Industry (Ville de Laval, 1998a). Laval Technopole's mandate includes promoting the establishment of companies related to the five principal sectors of economic activity - biotechnology, agriculture, information technology, aerospace, and manufacturing, and by providing them with assistance in investment, market development, exports, networking and outsourcing (Laval Technopole, 1998; Ville de Laval, 1998a).

Two of the nine target areas identified in the strategic plan of Laval were the agricultural sector and the environment (CDRL, 1995) and these elements form the basis of the following two sections.

4.6 Agricultural Profile of Laval

According to Laval's strategic plan, the major challenges facing the development of the agricultural sector include (CDRL, 1995):

1. Respecting and maintaining the permanent agricultural zone
2. Keeping the channels of communication open to ensure a favourable climate
3. Establishing mechanisms to ensure the harmonious integration of agricultural and urban activities; and

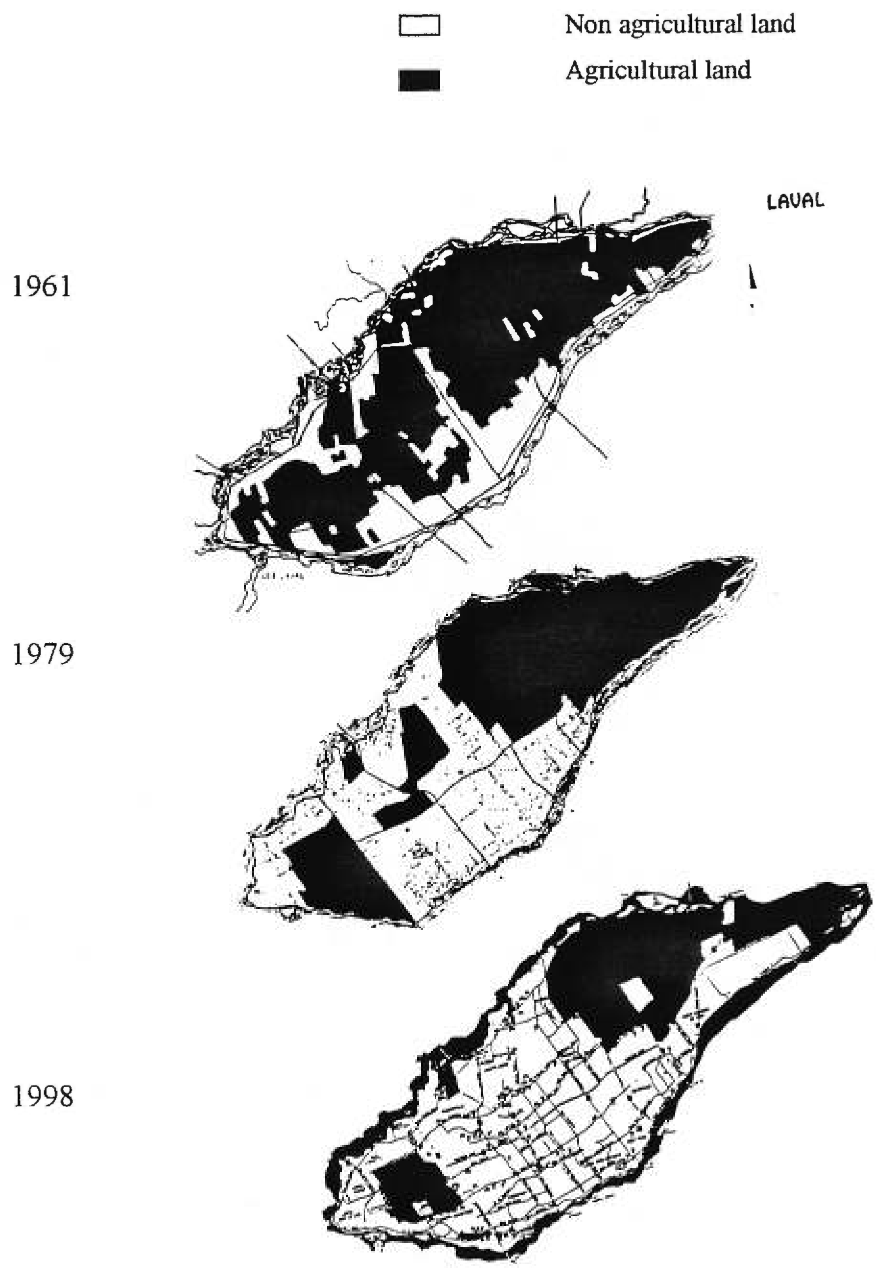
4. Focusing on the commerical development of the horticultural industry within a competitive market.

Thus agricultural activities are considered to be part of Laval's "dynamic yet structured economic plan", with the services of Laval Technopole supporting producers, or "entrepreneurs", in developing their ability to succeed in "carving niches and capturing substantial market share in several sectors" (Laval Technopole, 1998). The particular mandate of the Agropôle, which includes the Armand Frappier Institute (with its plant physiology laboratory), the Laval Centre of Horticultural Services, the Laval Horticultural Training Centre, Laval's culinary school, etc. is to:

> "(Develop) and (promote) horticulture and agriculture in Laval, because in Laval, these sectors are considered an integral part of the economy." (Laval Technopole, 1998).

Ten years after the introduction of the Act for the Protection of Agricultural Lands, the Commission led a province-wide review which reduced the proportion of Laval's agricultural zone from 47% to 30% of its territory (CPTAQ, 1995). By 1998, that proportion had been further reduced by various means to 28% (CPTAQ, 1998; Ville de Laval, 1998a). The evolution of Laval's agricultural zone is illustrated below in Figure 4.2.

Figure 4.2 Changes to Agricultural Lands in Laval from 1961-1998



Virtually all of the production in the primary sector of Laval's economy comes from agriculture (most of the quarries are closed), however this accounts for only 1% of total employment, down from 2.5% in 1981 (Archambault, 1987; Ville de Laval, 1998a). Between 1995 and 1998, the number of farms in Laval declined from over 250 to less than 200, however the proportion of the agricultural zone that was in production rose to 72% from 62% (CPTAQ, 1995; 1996; 1997; 1998). Agricultural activities on Île Jésus are concentrated either in the *field* production of grains, melons, vegetables, ornamental shrubs and plants, or in the *greenhouse* cultivation of numerous types of flowers, plants, vegetables and shrubs - total revenues reached $32 million in 1995 (Gouvernement du Québec, 1995c). A résumé of the agricultural profile of Laval appears below in Table VIII.

Table VIII Agricultural Profile of Laval

Type of production	Number of producers in Laval	Area under cultivation
Vegetables	106	1 755 ha
Cereals & grains	24	1 828 ha
Fruit and small fruit	31	116
Silage (for animal feed)	32	N/a.
Greenhouse production: mushrooms; herbs; flower and vegetable plants	134	450,423 m^2
Ornamental horticulture: trees & bushes *in containers*	8	4 ha
Ornamental horticulture: trees, bushes; perennials, etc. *in the field*	28	73.5 ha
Other types of vegetable production	15	153 ha
Land not in production		
Fallow	34	113 ha
Abandoned	34	129 ha
Woodlot	56	186 ha
Yards & buildings	199	145 ha
Other	24	51 ha
Total area		
Land in production	204	4667 ha
Land not in production	204	624 ha
Land owned	197	2015 ha
Land rented	85	3276
Total area (of agricultural zone)	**212**	**5291**

(Source: Gouvernement du Québec, 1995c, Bureau de la statistique du Québec, 1996).

Horticultural production forms the basis of a $1.2 billion dollar industry throughout Québec, with over $200 million in farm sales alone, generating more than 11% of the revenues of the biofoods sector in Québec, behind dairy and pork production and creating 23,500 jobs (Gouvernement du Québec, 1995a; 1995b). Horticultural production is a major component of agricultural development of the region and Laval Technopôle has organized numerous promotional and public events to benefit this sector, including the "Effleure-printemps" horticultural exhibit, the food fair "Le bon goût de notre campagne", the "Bal des Fleurs" and its gardening contest, the agri-food fair "Salon de l'agrotourisme et du terroir" (Laval Technopole, 1998). Laval refers to itself as the horticultural capital of Québec, and by 1998, the 170 greenhouses in the region were responsible for 35% of the province's hothouse flower production (Laval Technopole, 1998). Between 1995 and 1998, seven new farmers specializing in horticulture received 30% of the funds allocated to the region under the provincial government's financial aid program for farm start-ups (Gouvernement du Québec, 1998e). In 1995, the average farm size in Laval was almost one-quarter that for the province, 25 hectares compared to 98 hectares, but by 1998, it had risen to 40 hectares, an increase of 60% (Gouvernement du Québec, 1995a). The total area of the agricultural zone devoted to all types of greenhouse production had increased by 44% within the five-year period of 1991-1996 (Gouvernement du Québec, 1995a, 1995c; Statistique Canada, 1996). This trend is in keeping with the demands of the horticultural marketplace, since the establishment of large-surface retail outlets puts pressure on producers to fill big orders for their products, which, in turn, favours farmers who have large-scale operations (Gouvernement du Québec, 1995a).

Sustainable agriculture is defined as:

> "An economically and environmentally viable alternative to both industrialized and organic agriculture...which seeks...to achieve profitable and efficient production...without (returning) to low technology or low output farming. It is a spectrum of technologies and practices which usually involve the substitution of labour, knowledge and management skills for the high use of external inputs." (Pretty & Howes (1993), cited in Barrow, 1995).

The overfertilization of soils, loss of organic matter, and pollution of groundwater and rivers and streams from agricultural run-off are some of the negative environmental consequences associated with intensive agriculture (Brady & Weil, 1996). The development of sustainable agroecosystems relies, in part, on integrated resource management (Barrow, 1995) such as the implementation of cost-effective, non-polluting soil management techniques. The use of quality compost from the agricultural, forestry, industrial, fishing and urban sectors is recognized as a component for promoting the sustainability of Québec farms (Gouvernement du Québec, 1993; Gouvernement du Québec, 1998a) since it would reduce farmers' reliance on synthetic fertilizers and pesticides. The introduction of compost into farm soil management schemes improves soil quality, reduces pest infestations, and generates yields greater than or equal to those achieved when synthetic fertilizers and pesticides are used (Hoitink et al., 1997; ISHS, 1997; Porter, 1999). The development of properly managed municipal composting programs could provide (nearby) farms with a steady source of top quality compost, thus helping to promote the sustainable use of land for both agricultural and urban functions, by closing the nutrient loop. Furthermore, the reduction of wastes at source is one of the strategies required to lower the overall impact of the "wasteful cities of the North" (White, 1992). It is estimated that the "ecological footprint" of a particular population could possibly be reduced by 50% if compost from urban organic wastes were returned to the "foodlands" from which resources are drawn (W. Rees, 1998, personal communication). Adopting such a strategy will require the development of effective municipal organics collection and recycling programs. In the next section, we examine the issue of solid waste management in Laval, with particular emphasis on the 3-stream collection program that, in fact, has been very successful in producing top quality compost from urban organic materials.

4.7 Solid Waste Management in Laval

Waste management in Laval has evolved considerably since the early years of the 20th century when the mayor's tasks included, amongst other things, driving through the streets in a horse-driven wagon to collect municipal refuse (Dauphinais & Marien, 1981). The first municipal garbage truck purchased by the city in 1947 was sufficient to cover the territory (Dauphinais & Marien, 1981). By 1997, a fleet of 34 trucks in summer and 24 trucks in winter was required to collect the 150,000 tonnes of waste generated annually by the 335,000 residents of Laval (Ville de Laval, 1996; Ville de Laval, 1998b). The four original landfill sites on Île Jésus (Saint-Judes in Chomedy, Bomar in the center of Laval, Cloutier in the east and the Centre de la

Nature in Saint-Vincent-de Paul) which once received waste for disposal from outside the region of Laval, primarily from the metropolitain area of Montréal, are now closed (Ville de Laval, 1996). All domestic waste currently collected in Laval is delivered by the various private companies under contract with the City to a transfer station before being transported to a site in Sainte-Sophie at a cost of $30/ton (BAPE, 1997b; Gouvernement du Québec, 1998c; Ville de Laval, 1998b). In 1997, 88% of the City of Laval's public hygiene budget was spent on the collection of domestic solid waste, at a cost of $12.7 million or approximately $34/door (Ville de Laval, 1998b).

In 1996, the City of Laval sent representatives to participate in the public hearings on the subject of waste management in Québec. The City's official position was presented to the BAPE Commission, and it outlined an approach that espouses the integrated management of solid waste. Many of the arguments presented in this document for the need to develop innovative programs for waste reduction are based on conclusions drawn from years of experience regarding the success of most door-to-door programs for the collection of recyclable wastes, where diversion rates rarely surpass 15%. The City of Laval's position is that the collection of organic materials is essential for reaching waste reduction objectives of 50% or higher (Ville de Laval, 1996). Furthermore, it is stated that the production of quality compost can only be assured in a program where organic materials are separated at source and that a low technology option, such as windrow composting, is feasible even in Québec's climate:

> "Nous croyons que...le ramassage séparé de la matière organique, est la condition essentielle pour produire un compost de qualité qui soit utilisable...et d'autre part, que le compostage en andains, qui est la façon la plus économique de composter, est un procédé tout à fait viable même sous nos latitudes et même en incorporant les résidus alimentaires." (Ville de Laval, 1996, pp. 2,9).

The profile of the various waste reduction programs appears below in Table IX.

Table IX Waste Reduction Profile

	1998	
	Population	Occupied Units
Residential buildings with 1-7 units		101 409
Residential buildings with 8 units or more		28 972
Total residential		130 381
Industry, commerce, institutions (ICI)		11 211
TOTAL	**337 000**	**141 592**

ACTIVITY	Door-to-door, etc.	Tons	Percentage
WASTE GENERATED		**162 789**	**100.00%**
		1 150 kg/unit/year 483 kg/person/year	
RECOVERED MATERIALS			
RECOVERED RECYCLABLE MATERIALS		16 839	10.34%
RECOVERED HAZARDOUS MATERIALS		94	0.06%
RECOVERED ORGANIC MATERIALS			
3-stream collection program (Champfleury district)	1 500 doors	643	0.39%
Domestic composters (50kg per composter)	8 257 units	413	0.25%
Dead leaves (door-to-door pick-up)	101 409 doors	250	0.15%
Dead leaves (voluntary drop-off)	3 deposit sites	43	0.03%
Christmas trees (voluntary drop-off)	12 deposit sites	7	0.00%
TOTAL ORGANIC MATERIALS		1 356	0.83%
		18 289	**11.23%**
		129 kg/unit/year 54 kg/person/yr.	
LANDFILLED MATERIALS			
		144 500	**88.77%**
		1 021 kg/unit/year 429 kg/person/yr.	

Source: Service des travaux publics et de l'environnement urbain, Ville de Laval, (1999) Laval has achieved an overall diversion rate of 11.23% for solid waste through the implementation of numerous programs such as the collection of recyclables, schools' wastepaper, dead leaves, Christmas trees, and other organic matter via domestic and municipal composting programs (Ville de Laval, 1999).

4.7.1 The Collection of Recyclables

In 1990, the City of Laval started collecting recyclable materials and by 1996, 20% of the population was being serviced by door-to-door collection, with the rest of the population having access to 30 drop-off points throughout the territory (Ville de Laval, 1996). In 1998, the collection of recyclable wastes was extended to all buildings with seven apartments or less (approximately 101,00 buildings or 261,000 doors), thereby increasing to 78% and 8% the proportion of the population with door-to-door collection and drop-off services, respectively. The total amount of recovered recyclable materials was 16,839 tons, or 10.34% of Laval's solid waste stream (Ville de Laval, 1999).

4.7.2 Hazardous Waste

The City of Laval has an arrangement with local outlets of RONA and Canadien Tire stores, where citizens can deposit old paint and used oil, respectively. Overall, 6% of materials recovered from the Laval waste stream is in this category.

4.7.3 Domestic composting

As of 1998, the City of Laval had distributed composter units to over 8,250 households representing 5.1% of the total number of dwellings throughout the territory. In Laval, the estimated amount of organic waste diverted through domestic composting is 413 tons, or 0.25% of all solid waste.

4.7.4 On-Farm Leaf Composting

A municipal program for the collection of dead leaves and Christmas trees was introduced in 1993, and, by 1998, this service had been extended to the entire population of Île Jésus, including three voluntary deposit sites (Gouvernement du Québec, 1998c; Ville de Laval, 1999). Three hundred tons of leaves and Christmas trees were diverted from landfill in 1998, accounting for 0.18% of the solid waste stream in Laval. The collected leaves are delivered to 15 farms on the island where they are composted using specialized equipment that was purchased by the City but that is operated by an entrepreneur who travels from farm to farm in order to process the leaves (Stéphane Larose, Laval farmer, 1998, personal communication). This arrangement may augur well for the acceptance of municipal compost by the agricultural sector.

4.8 The 3-stream Collection Program

In December 1996, the Department of Public Works and the Urban Environment began a pilot project for the door-to-door collection of domestic organic materials (food residues, grass clippings, dead leaves) in addition to the regular pick-up service of recyclable and non-recyclable wastes - hence the name 3-stream collection. The Champfleury sector of the Ste-Rose district had been previously selected following consultation with staff at another city department (Serge Benoît, Demographer, City of Laval, 1999, personal communication) as a site for testing various projects related to integrated waste management (Ville de Laval, 1998c). Since the main criterion for the implementation of the 3-stream project was a sector where the population was already serviced by door-to-door pick-up of recyclable wastes, the Champfleury sector was deemed appropriate. This subdivision, with 1,500 single-family dwellings with an average lot size of between 460 m^2 and 560 m^2 and with 15-year old trees, was chosen. The socioeconomic profile of this sector is one of a well-educated, middle-class population comprised mainly of young families. Those in charge of the pilot project established multiple channels of communication with residents by setting up a series of information meetings and a special telephone line through which members of the technical team were available for consultation. Residents received the necessary implements (a seven-liter collection bucket for use inside, a 240-liter bin for use outside, information pamphlets, stickers and reminders). Over 90% of those who were contacted agreed to participate in separating their organic waste and bringing it out to the curb in the appropriate bin once every two weeks during the winter months and once a week in summer. The regular collection of recyclable wastes continued, however the pick-up of the separated organics replaced one of the bi-weekly collections of domestic waste. Although the amount of organics collected varied throughout the year, the 3-stream program was considered an unmitigated success, boasting a total diversion rate, including recyclables, of 44.28%. The 44.28% diversion rate was achieved by collecting 15.63% of all recyclables and 28.65% of all organics, 330 and 606 tons, respectively. An average garbage bag is comprised of approximately 34.8% organic materials (GRAIGE, 1989), however, in sparsely-populated residential sectors where lots with single-family dwellings have both yards and trees, the *potential* rate of diversion for *organics* is actually higher (due to the presence of grass clippings and leaves). In the Champfleury district of Laval, the potential *organics* diversion rate was estimated at 50.38% (Ville de Laval, 1998c). Furthermore, the estimated potential rate of diversion for *dry recyclables* throughout Québec is 27.71% (Gouvernement du Québec, 1994). Thus the *combined potential diversion rate* for Laval (organics -or wet - and dry recyclables) is 78.09% (50.38% + 27.71%), with the recovery of the organics component contributing 1,066.47 tons of compostable materials from Champfleury alone (Ville de Laval, 1998c). An estimate of the potential for the collection of organics throughout the territory of Laval appears below in Table X.

Table X Potential Recovery of Organics in Laval

	All of Laval	Champfleury Project
Residential units	130,381	1,500
WASTES GENERATED	162,789 m.t.	2,116 m.t.
Recovered organics	713 m.t.	606 m.t.
Actual Proportion	0.43%	28.65%
POTENTIAL ORGANICS RECOVERY		
28.65%	46,639 m.t.	606 m.t.
34.8% *	56,650 m.t.	736 m.t.

* (GRAIGE, 1989) ** (Ville de Laval, 1998c)

4.8.1 Composting organic materials

The organic materials collected through the 3-stream program are composted at the snow dumpsite in the western part of the Fabreville district. There is a 2,500 m^2 area reserved for composting at the northeastern tip of the 27,000 m^2 site, which is bordered to the south and east by an industrial zone, to the west by the agricultural zone, and to the north by residential zones. The composting pad and operations conform to the specifications of the Ministère de l'environnement et de la Faune du Québec regarding soil permeability, drainage, and preliminary treatment of collected wastewater. Some of the dead leaves and shredded woody materials that are collected throughout the territory are directed to the site and are used as a source of carbon, with the organic materials collected in the door-to-door program providing the source of nitrogen. Windrows of mixed materials, measuring five meters wide by two to two and one-half meters high by 30 meters long, are formed through the use of a front-end loader and the piles are turned once a week in winter and 5 times a week during the summer months. The cycle for producing compost with this method takes approximately 12-16 weeks, depending on climactic conditions, and during the winter, the period can be extended up to 20 weeks. Once the compost has sufficiently matured, it is passed through a screen with a 1/2 - 3/4 inch mesh to remove residual particles. The quality of the compost produced during the first phase of the pilot project was assessed by independent laboratories and the results showed that samples conformed to most of the specifications for Category AA or A compost (Ville de Laval, 1998c). Some of the results are presented below in Table XI.

Table XI Test Results for Compost Produced by the City of Laval

PARAMETER	BNQ STANDARD	RANGE COMPOST SAMPLES
C/N Ratio	25	15.86 - 22.25
Humidity	< 60%	30 - 51.4%
Organic matter	50 (AA) 40 (A)	25.8 - 43
Fecal coliform	1000 ufc/g	0 - 200
Foreign matter % dry weight Max. size in mm	≤ 0.01 (AA) ≤ 0.5 (A) 12.5	No samples conformed to standard**
Trace elements Cadmium Lead Mercury	 3 150 0.8	 < 0.5 – 0.8 17 – 35 < 0.2 –0.6

Source: Ville de Laval, 1998c, p. 44.
** Due to the presence of rocks; corrective measures planned for Phase II of project.

4.9 Directing urban-generated waste to the agricultural sector in Laval

Composting programs that rely on source-separated organics consistently produce top quality compost (Ledgerwood, 1999; Ville de Laval, 1998c), increasing the likelihood that the agricultural sector would be receptive to accepting this type of urban-generated soil amendment (Goldstein, 1999). If horticultural operations in Laval continue to grow as projected, the production of quality compost through municipal activities and its acceptance on local farms, may provide an opportunity for fostering the development of sustainable agricultural and waste management practices by closing the nutrient loop. This process begins by:

> "Thinking about compost as a valuable product, and shift(ing) our thinking away from considering it as purely waste management issue." (Lemmes, 1998)

It is not likely that farmers will become "the waste managers for their nations" (Butterworth, 1998), however there are viable reasons to include this sector when considering certain issues related to the management of municipal organic wastes.

The following section reviews the extent to which municipally produced compost could be absorbed by Laval's agricultural sector.

4.10 Compost Supply and Demand

83-93% of all plant producers (greenhouse, vegetable, cereal, horticulture) are concerned with the impact of using chemical fertilizers, including problems of soil degradation and groundwater pollution, 44-60% plan on using compost to correct soil problems, however only 26% have the time or equipment required to produce compost (Zins Beauchesne, 1997). Farmers have misconceptions regarding the nature and properties of compost, and often confuse it with manure. Only 12% of conventional greenhouse producers were able to identify the composition of the 200 m^3 (or 114 tons) of compost that they use on an annual basis, however between 68%-87% expressed an interest in using top quality compost (Zins Beauchesne, 1997). The market study from which this data is drawn concludes that the demand for compost by conventional and organic plant producers is 54,645 tons and 64,230 tons, respectively, with an expected growth rate of 4,018 tons and 10,906 tons, respectively, during a two to three year period. A comparison of the estimates of potential municipal compost production and agricultural use for the Laval region appears below in Table XII.

Table XII Potential Supply and Demand for Compost in Laval

Producers	Average compost use per producer*	Estimated potential compost use in Laval	Estimated potential compost production in Laval
Greenhouse (134) Horticulture (36)	1,148 tons 8 tons	15,383 tons 1072 tons	
TOTAL		16,455 tons	23, 000 tons

*(1.0 $m^3 \cong 0.574$ ton)

During the first year of operation of the 3-stream collection program, 470 tons of compost was generated. With an organics *recovery* rate of 28.56% and at a *participation* rate of 50%, it is estimated that approximately 23,000 tons of organic material could be collected if this program were extended throughout Laval. Currently the City of Laval spends approximately $13 million on waste management, with the 2-stream collection service costing approximately $78 per household excluding administrative costs (Ville de Laval, 1998b, 1998c). The 3-stream collection program is assessed at $108 per household, $40 of which is directly attributable to the start-up costs of the organics program (André Giroux, Waste management consultant, Ville de Laval, 1999, personal communication; Ville de Laval, 1998c). Since landfilling a ton of waste in Québec costs approximately $34, diverting 23,000 tons of (residential) organic materials from the waste stream would translate into a maximum savings of $782,000.

One of the objectives of the second phase of Laval's pilot project is to improve the economic viability of the 3-stream collection option by integrating the recovery of organics from the ICI sector (Ville de Laval, 1998c). In fact, throughout Québec, the ICI sector annually generates 188,000 tons of degradable waste and the government is encouraging this sector to develop the mechanisms for recovering 60% of this waste, or 113,000 tons, within 10 years (Gouvernement du Québec, 1998b). A minimum production of 23,000 tons of compost from residential organics recovery, combined with that of the ICI sector, would meet the estimated demand of 16,455 tons by the agricultural sector. There would be sufficient compost left over to replace the annual purchase of approximately 125 tons of soil amendment by the parks department for the maintenance of its green spaces, thereby realizing a savings of at least $7,000 (Yvan Péloquin, 3-stream program coordinator, Ville de Laval, 1998, personal communication). Sufficient compost would be left over to supply the bi-annual open door visits to the composting site at which time the public purchases approximately 200 tons of compost, generating revenues of between $4,000-$5,000 (Ville de Laval, 1998c). Windrow composting, the technique currently used in Laval, is considered a low cost and low technology option, however it requires the greatest amount of space when compared to other composting techniques (Gouvernement du Québec, 1993a). The expansion of the municipal composting program would necessitate a feasibility study regarding the availability of suitable sites on or near Île Jésus.

4.11 Conclusion

The original intent of our research was to include the results of a survey with Laval farmers on their willingness to accept municipally produced compost. Despite the absence of this data, we believe that this case study aptly demonstrates that many of the conditions required for creating a sustainable link between the urban and agricultural sectors, by closing the nutrient loop, are currently in place. In particular:

1. The City's strategic plan identifies, as one of its objectives, the promotion of the agricultural sector;
2. The City's policy on integrated waste management recognizes certain principles related to sustainable development at the municipal level; and
3. The 3-stream collection program has proven effective in producing compost of a quality acceptable for horticultural production.

Whereas Laval may have been slightly ahead of its time when the 3-stream collection project was first introduced in 1996, this option now fits seamlessly into the scenario made possible by recent developments in the fields of land use and urban planning, agricultural protection and waste management in Québec. Furthermore, there appears to be an interest, on the part of municipal decision-makers, of exploring the possibility for directing muncipally-generated compost to the local agricultural sector (Yvan Péloquin, 1998, personal communication). The development of linkages between municipal organic waste management practices and agricultural soil management programs must reflect the requirements of each sector. Thus, consultations with municipal and agricultural sector representatives and community members, as well as surveys with farmers, are required for ensuring that locally relevant programs are developed. We believe that Laval is currently positioned to undertake initiatives that will enable it to develop a sustainable waste management system, thereby contributing to the promotion of urban sustainability. In more general terms, the next chapter reviews some of the procedures that are involved in the planning of sustainable waste management systems.

Chapter 5 Closing the Resource Loop

5.1 Introduction

The long-term goal of achieving a "social-environmental system in balance" underlies the concept of sustainability, however there is no single formula for achieving this end. Urban planners are called upon to reconcile the seemingly divergent interests of economic development, social equity and environmental integrity contained within the "triangle of planning conflicts" (Campbell, 1996). There is a "danger" that in planning (and other fields), the fundamental changes required for achieving this goal can be avoided by simply:

> "Adding the term "sustainable" to all our existing planning documents and tools...without easily break(ing) (it) down into concrete short-term steps...(and) ever...actually measuring it or even know(ing), one day in the future, that we had achieved it." (Campbell, 1996, pp. 301-302).

Sustainability can be interpreted at various levels throughout the urban environment (Ravetz, 1996) and one concrete, short-term, and measurable step towards urban sustainability is the implementation of effective and efficient waste reduction and management systems. The cost-effectiveness of a waste management system alone does not contribute to sustainability if the practices employed do not reverse patterns of over-consumption within society or lessen environmental degradation. When elements of waste management systems are coordinated with other sectors, resource loops can be closed and consumption levels lowered, thereby contributing to the preservation and not the destruction of ecosystems (Rees, 1992; Roseland, 1994).

Regulations are often necesssary to ensure this level of coordination. Paper recycling, for example, theoretically creates multiple links through local job creation, trade of secondary resources and, ultimately, reduced demand for virgin forest products, however the contribution to sustainability is limited if all members of society do not invest commesurate levels of effort towards achieving a common goal. The life cycle analysis tool informs the work of contemporary municipal waste managers who should also be encouraged to envisage closed resource recovery loops and establish partnerships with other sectors in an effort to promote sustainable practices (Dumble & Whittaker, 1998).

Traditional waste management systems focus primarily on "end-of-pipe" solutions such as waste collection and disposal, primarily through landfilling and incineration (Furedy, 1995). *Integrated* systems place greater emphasis on selecting suitable techniques for managing municipal solid wastes based on the most effective use of economic and energy resources (MacDonald, 1996; Tchobanoglous et al., 1993; P.R. White et al., 1995). *Sustainable* waste management systems are designed to achieve effectiveness, yet the short-term market approach is supplanted by a longer term outlook aimed specifically at conserving resources for future generations (Dumble & Whittaker, 1998). The first section of this chapter reviews the performance of solid waste management systems and the second section examines the role played by organics recovery and composting programs in closing resource loops, which is considered a prerequisite for achieving some of the environmental objectives associated with sustainability.

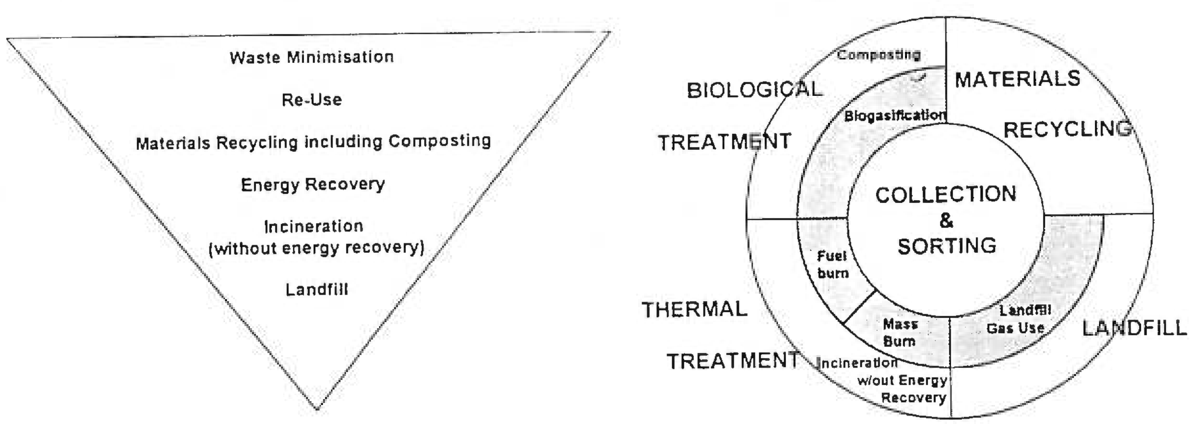
5.2 Performance of Solid Waste Management Systems

Integrated waste management systems are based on a hierarchy of the 4R's: *Reduction* of waste at source is the most effective option, followed by *Reuse, Recovery* (or transformation), *Recycling*, and succeeded by *elimination* (incineration or landfilling), the option offering the least effective use of resources (BAPE, 1997a; Chevalier, 1995; Furedy, 1995; Murray, 1995). A more holistic approach to integrated waste management is based on analyzing the nature of the relationship between the various elements of the system:

> "Rather than a hierarchy of preferred waste management options, an holistic approach is proposed which recognises that all disposal options can have a role to play in integrated waste management...The model stresses the inter-relationships of the parts of the system...the overriding objective is to optimise the whole system, rather than its parts, to make it environmentally and economically sustainable." (P.R. White et al, 1995, p. 21).

A comparison of the hierarchical and holistic approaches to solid waste management systems appears below in Figure 5.1.

Figure 5.1. Hierarchical and holistic view of solid waste management systems



Hierarchical view

Holistic view

Source: P.R. White et al. 1995, pp. 20-21

5.2.1 Recycling

Recycling is defined as the reuse of material in a production process that diverts it from the waste stream and the *recycling or diversion rate* is the ratio of the quantity of material recycled (paper, cardboard, glass, aluminimum, etc.) to apparent consumption (OECD, 1997). Recycling is considered to be an economically feasible waste managment option wherever the net costs are less than the cost of waste disposal (Solid Waste & Recycling, 1998). Residential recycling was one of the first alternatives to disposal to catch on throughout North America. In 1990, voluntary national targets for waste reduction (of 50% by the year 2000) were embodied in the National Protocol on Packaging after multistakeholder consultation between the Canadian Council of Environment Ministers, the provinces, territories, federal government, municipalities, private sector interests and environmental groups, with the understanding that regulations would be adopted to reach this target (Murray, 1995). By 1991, municipal recycling programs were available to 86% of households across Canada and to 74% in Québec (Statistique Canada, 1994).

There are limits in relying exclusively on any one option for reaching waste reduction targets and when waste management objectives and priorities are neither clearly defined nor consistently applied, the different mechanisms can actually work at cross-purposes. An example of this is the competition for "trash" which developed when (American) state funding of both recycling and energy-generating (resource-recovery) incineration activities forced both options to go after the same materials (Heinen, 1995; Steingraber, 1997):

> "...the decision to invest in an energy recovery facility reduces the attractiveness of putting resources into a local recycling program....Incineration costs depend on the energy content and completeness of combustion of the incoming waste stream. In general, recycling programs that remove paper and plastics from the waste stream render incineration more expensive, while recycling that removes metals (other than aluminum), glass, yard waste, and large unburnable items make incineration less expensive". (Keeler and Renkow, 1994, p.211)

5.2.2 Reduction

Municipal solid waste managers realized the importance of increasing efforts to promote waste reduction and composting by the end of the 1980's despite the success that had been achieved by the joint residential recycling program of the Ontario municipalities of Gloucester, Nepean and Ottawa where diversion rates reached 11.6% by 1989 (Haight, 1991). In Québec, the overall recovery rate of recylable *municipal* solid waste doubled during a ten-year period, reaching 33% by 1996 (Gouvernement du Québec, 1998; OECD, 1997; Statistics Canada, 1994), however recovery rates from *all sectors* combined lowers total waste reduction to 17%, far below the target of 50% (Gouvernement du Québec, 1998). The apparent success of a particular option, such as recycling, may give the false impression that there has been progress towards waste reduction. In other OECD countries over the last 10-15 years, waste reduction has turned out to be a very elusive goal with rates of waste generation per capita either stabilizing or increasing (OECD, 1997). There is a consensus that innovative strategies must be developed for effectively reducing wastes at source (Argue, 1998; Gouvernement du Québec, 1998a; Skerbeck, 1998), a message reiterated by numerous intervenors during the public hearings on solid waste management in Québec (BAPE, 1997a). The greatest success to date in waste reduction has been achieved in jurisdictions where combinations of source-separation programs have been introduced: 41% in Laval (please refer to Chapter 4); and up to 65% in some communities in the provinces of Ontario and Prince Edward Island (Argue, 1998).

5.2.3 Recovery (or transformation)

The practice of composting has generally been associated with the organic farming movement and not with the organized management of municipal organic waste in the developed world (Furedy, 1995), therefore a shift in thinking is required to incorporate this practice into the urban environment. Despite the overall increase in the number of North American municipalities offering organics recovery programs within the past decade (Antler, 1998), the future of these initiatives is uncertain if markets and dedicated uses for municipally-generated compost are not developed (C. Gélinas & J.-P. Panet, Ville de Montréal, 1999; Y. Péloquin, Ville de Laval, 1998, both personal communication).

> "A number of communities have adopted aggressive recycling policies...While their intentions are commendable, acting on the value judgment alone has led to a number of difficulties because of inadequate markets for secondary materials and excessive costs. Had costs and level of demand also been considered, better decisions might have been made." (MacDonald, 1996, p. 238).

Transforming municipal organic residues into compost, and developing safe uses for this secondary resource within or without the urban environment, closes a nutrient loop and helps promote sustainability (Dumble & Whittaker, 1998). A sustainable system emerges when waste management operations are linked with other functions in the urban environment (Ravetz, 1996) and ultimately with the city's rural and global hinterland (Gardner, 1997; Nicholson-Lord, 1989; Rees, 1996; P.R. White, 1995) especially if those uses help maintain the ecological integrity of various (eco)systems. There is a growing interest in the issue of recycling organic wastes: research on the efficiency of waste collection as well as on the quality and applicability of composted urban waste is increasing (UAN, 1997) and at a 1996 conference entitled *Recycling Waste for Agriculture: The Rural-Urban Connection*, it was stated that coordinated global action could only be triggered on this issue:

> "When public understanding of the tremendous untapped value of municipal wastes reaches critical mass, and when this public understanding forces policy makers to face up to waste recycling issues." (World Engineering Partnership for Sustainable Development, World Bank, 1996).

Linking the recovery of municipal organic wastes to the development of environmentally sound soil management techniques is an even more daunting challenge since the reuse of organic materials will ultimately depend upon fundamental changes taking place in agricultural production and trade practices (Gardner, 1997). Despite these difficulties, it is thought that the scenario presented in Chapter 4 presents an example of how such a linkage could occur on a small scale.

5.3 Closing the Loop

The representation of cities as "spatial expressions of systems of human social organization" with linear, *open* flows of matter, energy and ideas (Hughes, 1972) is modified when *closed* resource recovery loops are recognized as important components in the development of sustainable solid waste management systems (Ayres & Weaver, 1998). Life Cycle Assessment technique, normally used to assess the environmental impacts of a product or service from cradle to grave has been borrowed by the field of solid waste management to assess the sustainability of various waste management options (Dumble & Whittaker, 1998; P.R. White et al., 1995). Of the four distinct stages in the lifecycle assessment structure only the first two* have been applied to date in assessing various waste management options:

- *goal definition**
- *inventory**
- impact analysis and
- valuation

The inventory process is conducted by calculating the inputs (in terms of raw materials and energy) and outputs (in terms of emissions to air, water and as solid waste), which provide data for assessing the environmental impact of each procedure and for taking corrective measures if necessary (P.R. White et al, 1995). A sample of the type of information used during the inventory stage is presented below in Figure 5.2.

Figure 5.2 Lifecycle Inventory Procedure for Waste Systems

1. System studied: Composting (for example)

2. Data inputs

a) Types of data

Variable data which define the waste management system considered

Fixed data which define inputs and outputs for unit waste management processes.

b) Sources of data

Waste composition and amounts: International agencies, technical literature

Collection and sorting

Treatment processes: technical literature

c) Data quality

Overall poor quality, especially for waste quantity and composition

Data available for treatment of mixed waste stream

Little/no data on treatment of individual fractions of wate

3. Data outputs

a) System Inputs	Net Energy Consumption
b) System Outputs	Products: Amounts of recovered materials
	Amount of compost produced
	Emissions: Emissions to air
	Emissions to water
	Final solid waste
c) Performance Indicators	Materials recovery rate
	Overall recovery rate
	Diversion rate from landfill

Source: Adapted from P.R. White et al., 1995, p. 51

The elements required for the process of goal definition for organics resource recovery programs are examined in the next section.

5.3.1 Setting objectives for organics recovery programs

Some of the criteria that are useful to consider when developing objectives for organics recovery programs include:

Criteria Used When Formulating Objectives for Organics Recovery Programs

- The source of the material - municipal, industrial, commercial, institutional or agricultural sectors;
- The type of collection schemes in place, or to be developed - door-to-door source separated, voluntary drop-off sites, in-house;
- The type of use to which the secondary resource (compost) will be put - landfilling, landspreading, land reclamation, horticulture, agriculture; and
- The quality of the compost - according to national standards (for example AA, A or B of the BNQ)

1. If the program objective is to maximize diversion from landfill, without regard for the quality of the final product (for use in landfill or on degraded sites), then source-separated programs are not required (comingled wastes could be processed on-site) and the range of organic residuals collected is basically unlimited.

2. If the objective is to maximize diversion from landfill, producing compost for restricted use, then source-separated programs would be beneficial, but the range of organic residuals to be collected could also include materials with contaminants disallowed in the food chain.

3. If the objective is to maximize diversion from landfill, producing compost for agricultural use, then a restricted input of materials is required (primarily non-industrial feedstock) and source separated collection schemes must be implemented.

The objectives for the development of a closed organics resource loop within a sustainable integrated waste management system could be formulated this way:

To reduce waste and pollution by maximizing the diversion rate of municipal organic residues to composting programs and by increasing the proportion of municipally-generated compost that is designated to safe usages by establishing linkages throughout the community.

Methods for tracking the diversion rates for each component of the waste stream already exist and in communities with organics recovery programs, municipal waste managers routinely assess the percentage diverted from landfill (please refer to Chapter 4). Similar methods should be developed to keep track of the end-use of this secondary resource (compost) and to develop indicators for measuring the extent to which resource loops are being closed.

5.3.2 Examples of Closed Recovery Loops

Municipal solid waste contributes 25% of the total organic waste stream in Québec and approximately 35% of a typical residential garbage bag is comprised of organic waste (please refer back to Chapter 2). The ICI sectors (industrial, commercial, institutional) contribute another 45% to the total provincial organic waste stream (Gouvernement du Québec, 1998c). Sources of untapped organic materials within the urban environment, excluding the municipal residential sector, include food processers and retailers, public markets, schools and cafeterias, etc.. It has been estimated that within the territory of the Communauté urbaine de Montréal, the wholesale food market generates approximately 12,000 tons of compostable waste per year, with the Montréal Central Market contributing close to 4,000 tons alone (Rainville, 1990). It has also been estimated that the commercial food sector of the island of Montréal, excluding restaurants, contributes approximately 72 tons/week, with 1.5 tons coming from cafeterias, 3 tons from food processors, 4.8 tons from small fruit and vegetable retailers, and 62 tons from large grocery chains (Cimon, 1997).

Organic residues from these sectors of the urban economy are currently comingled with other waste and sent to landfill sites. The development of municipal organics recovery programs should not neglect these feedstock sources since they could significantly increase the volume of waste diverted from landfill, thereby ensuring the cost-effectiveness of resource recovery programs. Hotels, restaurants, public markets, and schools are additional sources of organic materials that should be tapped into. Creative solutions will be required to reach the 60% diversion rate for the organic waste stream slated for the year 2008 in Québec. The greening of local schoolyards, the enhancement of community gardens, the reclamation of brownfields, and the ecological maintenance of public spaces can all be assured through the planned development of sustainable municipal waste recovery programs.

Conclusion

6.1 General Conclusion

Adherence to the principles of sustainable development requires that a harmonious balance be achieved between economic, environmental and social concerns. When this objective guides public policy and program formulation, communities must be given the opportunity to define local priorities and to develop action plans that reflect the specificity of their respective milieus.

Within the context of urban environmental management, the selection of appropriate options for dealing with municipal solid waste is a strategic element that can create opportunities for employment, social development, and environmental conservation. The performance of municipal solid waste management programs can be measured using sustainability indicators by tracking the reduction in the quantities of wastes at source, for example. The separation, recovery and transformation of the organic component of the municipal waste stream has spawned the growth of centralized municipal composting facilities, often producing large quantities of usable compost. If this trend continues, the availability of large quantities of quality municipal compost will enhance the feasability of establishing links with players in the peri-urban agricultural sector. Directing municipally generated compost to agricultural applications has two benefits: wastes are reduced at source and a nutrient loop is closed both of which help reverse environmentally destructive patterns that have developed in the industrialized world during the last century. The aerobic composting of municipal solid organic wastes is thus one resource recovery option that can contribute to the attainment of sustainable waste management objectives.

In more traditional societies of the developing world, the practice of recycling urban organic waste has either persisted or has recently re-emerged within the context of urban agriculture. However most current examples in the developed world are limited to a few countries in Europe and to experimental field trials in the United States.

6.2 Recommendations for further research

During the course of our work, numerous interviews were conducted with individuals who were involved in designing municipal organics recovery programs and services.

One of the most notable concerns raised was the challenge for developing programs that are relevant and effective for every situation found in the urban context. Since most door-to-door organics recovery programs have been introduced in low-density, suburban neighbourhoods, there is little information on the effectiveness of programs geared to various sectors within the urban core (schools, hotels, markets, etc.). Hence, the first suggestion for further research would be to:

1. *Design innovative, small-scale composting projects appropriate for a high-density, inner-city neighbourhood.*

In communities where municipal composting programs currently exist, the resulting compost has been either given away or sold to members of the public at "open door" events in the spring and/or fall and also used in horticultural applications throughout the municipality. Municipalities should be encouraged to adopt ecologically sound landscape management practices throughout their respective territories by using municipally generated compost on all public green spaces and by eliminating the usage of synthetic fertilizers or pesticides. A second area of research would therefore be to:

2. *Develop municipal guidelines for adhering to environmentally responsible landscape management practices.*

Many large cities in North America have either publicly or privately run community gardens. Neither the production nor the use of compost in community gardens has been particularly successful, and so a third area for further research would be to:

3. *Develop strategies for overcoming the difficulties encountered in the production, acceptance and use of compost in community gardens as a means of promoting ecological urban gardening practices.*

Last, but certainly not least, is the issue of directing municipal compost to the agricultural sector, the central theme of our work. The success that has been achieved in the experimental field trials conducted in California indicates that there is receptiveness in that agricultural community for the supply of a quality controlled organic soil amendment. Given recent developments in Québec on issues related to agricultural production, land use planning and solid waste management, it appears that there will be more opportunities in the future to explore this type of arrangement between the municipal and agricultural sectors. Indicators such as diversion rates for various fractions of the solid waste stream provide a means of measuring the success of resource recovery programs. Collection of data on the use of secondary resources, such as municipally generated compost (and recycled paper and plastic, for that matter) is equally important in order to develop the means for analyzing the performance of closed resource loops. Thus, the fourth suggested area of further research is:

4. To develop an indicator to represent the extent to which a municipal recovery program contributes to closing a resource loop. This indicator would likely be expressed in terms of percentage of secondary resource used.

6.3 Concluding remarks

Within a context where the provincial government is proposing to ban the landfilling of green waste by 2002, and to recover 60% of organics by 2008, a clear signal is being sent on the importance of composting. In formulating our original query we asked whether it is realistic to direct municipally generated compost to a peri-urban agricultural sector, thereby closing a resource loop. In order to answer this question, we reviewed the elements deemed relevant to the development of sustainable waste management practices, focusing primarily on the organic fraction of the municipal solid waste stream. We then reviewed the current legislative and policy context in Quebec, with reference to initiatives in other jurisdictions, in order to highlight further changes that are required for significant advances to occur in the municipal, land use and waste management arenas. The municipal organic recovery and composting pilot project in Laval provided us with the opportunity to explore the notion that municipal waste management programs can not only effectively reduce waste at source, but more importantly, can also serve to reconnect the urban environment with a natural resource base. Our case study on Laval examines the potential for creating links with local area farmers by producing a reliable supply of a beneficial organic soil amendment from composted municipal organic materials. We suggest studying the feasability of expanding the City of Laval's 3-stream collection program as a precondition for developing these links and we believe that were this to occur, multiple benefits would accrue by promoting sustainable practices both in the fields of solid waste management and agriculture. Although most food and consumer products from which municipal compost is derived does not originate locally, urban dwellers indirectly involved in closing a resource loop by separating organic wastes and participating in composting programs will be sharing "black gold" with farmers in not too distant agricultural zones. Closing a resource loop has been identified as one of the requirements for reducing the negative impact of human settlements on the biosphere. It is hoped that this notion will continue to gain ground and that municipal waste managers and farmers will cooperate in the pursuance of recycling urban organic materials as common goal and that these efforts will be based on the recognition of the need to promote environmentally responsible agriculture and to foster a mutual recognition and harmonious interaction between the agricultural and the municipal worlds.

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APPENDIX

VARIOUS COMPOSTING PROCEDURES

(From: *The Practical Handbook of Compost Engineering*, Roger T. Haug, 1993, Lewis Publishers)

Nonreactor processes

The composting materials are not contained in a reactor, but left open, thus nonreactor processes are commonly referred to as "open" systems.

Nonreactor systems are divided between those that employ an *agitated solids bed*, where the composting mixture is broken up sometime during the compost cycle, and those that employ a *static bed*, where the compost piles are neither agitated nor turned during the compost cycle.

The Windrow Process (Illustrated below in A)
This is the most commonly used nonreactor, agitated solids bed system. Mixed feedstocks are placed in rows and turned periodically, usually by mechanical equipment. The height, width, and shape of the windrows vary depending on the nature of the substrates and the type of equipment employed. Oxygen is supplied primarily by natural ventilation (spaces between the materials) and by turning. In the forced air windrow system, oxygen is forced into the pile of materials with the use of blowers.

The Static Pile Process (Illustrated below in B)
Another example of a nonreactor, static solids bed system used primarily for treating wet substrates such as sewage sludge.

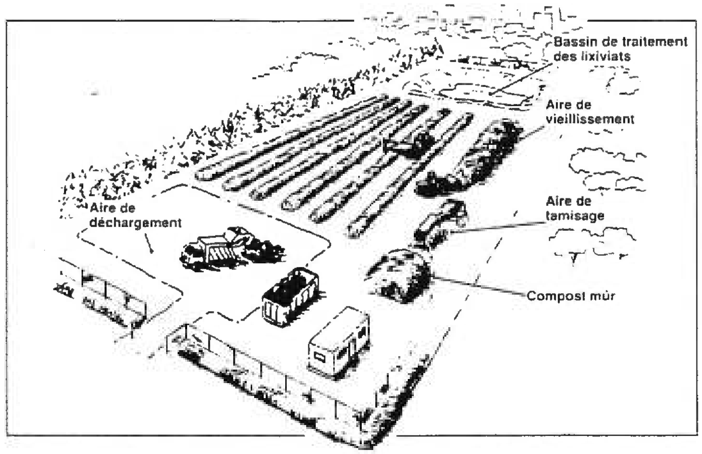
Reactor Processes

Reactor processes are classified according to the flow of solids within the system.

Vertical flow reactors (Illustrated below in C)
These systems include towers or silos, with agitated beds used primarily for treating sewage sludge amended with other mateirals such as sawdust.

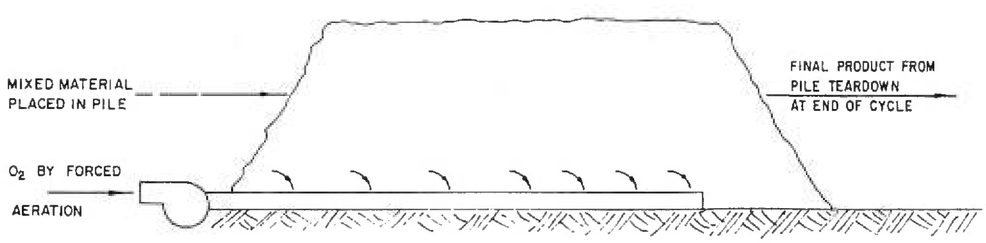
Horizontal flow reactors (Illustrated below in D)
These systems operate with a slight incline from the horizontal to promote solids flow and can have rotary drums or bins. Horizontal flow reactors with static solid beds have been applied to a wide variety of composting substrates including municipal solid wastes, agricultural wastes and sewage sludges.

A Typical set-up for windrow composting



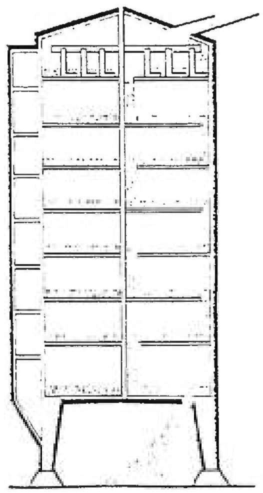
Source: Adapted from Gouvernement du Québec, 1993, p.44.

B Static Pile Process



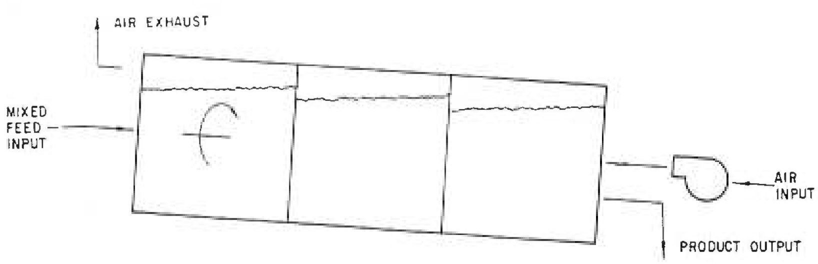
Source: Haug, 1993, p. 30.

C Vertical flow composting system



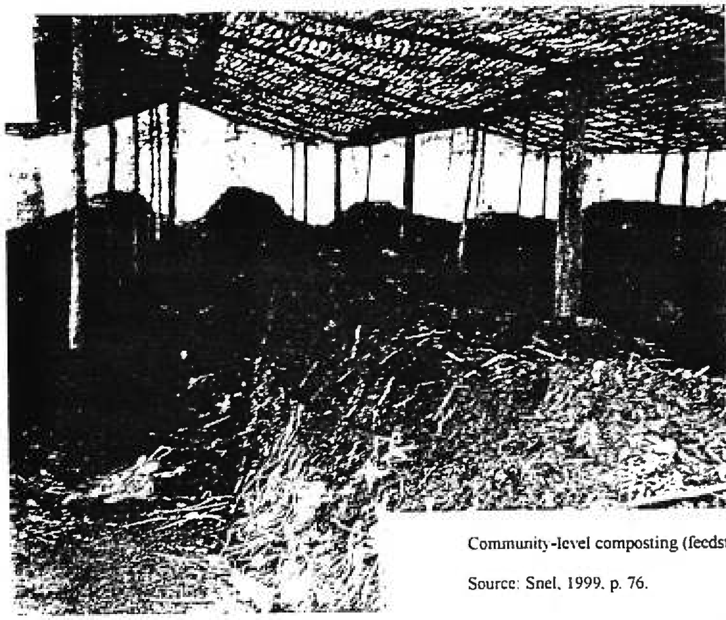
Source: Golueke, 1977, p. 83

D Horizontal flow composting system



Source: Haug, 1993, p. 36.

E Community composting

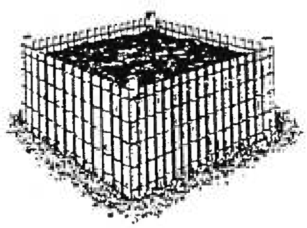


Community-level composting (feedstock from local markets)

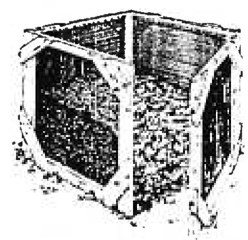
Source: Snel, 1999, p. 76.

F Domestic composting

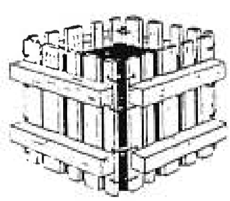
Containers used in Domestic Composting



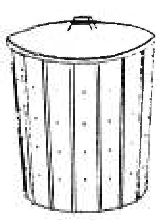
Contenant en clôture à neige



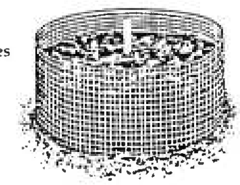
Contenant portatif en bois et broche



Contenant en palettes usagées

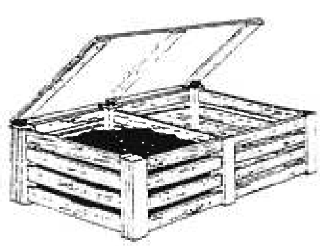


Poubelle perforée

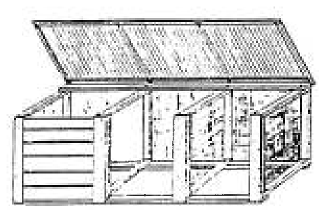


Enclos grillagé

Source : Nature Action, 1992



Contenant à 2 sections en bois



Contenant à 3 sections en bois et broche