IIIEE Master's Theses 2005:01

Composting in Polar Regions

An examination of quality related criteria for a source separation system in a polar community

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Thesis for the fulfilment of the
Master of Science in Environmental Management and Policy
Lund, Sweden, June 2005

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Published in 2005 by IIIEE, Lund University, P.O. Box 196, S-221 00 LUND, Sweden,
Tel: +46 – 46 222 02 00, Fax: +46 – 46 222 02 10, E-Mail: iiiee@iiiee.lu.se.
Printed by KFS AB, Lund.

ISSN 1401-9191

Acknowledgements

I would like to thank all those involved in helping me completing this work. A special thank to my supervisor Thomas Lindhqvist for his patience, constructive remarks and heartfelt support.

Abstract

Today's technology allows for communities based in polar areas to introduce composting as a way of handling organic waste. The success of this is dependent on a well functioning source separation system. The objective of this research is to examine a set of criteria that on an experiential basis influence the outcome of a number of quality aspects of a source separation system. From analysing the prevailing situation in Longyearbyen an estimation is made of the outcome of the quality aspects reflecting the level of functioning of the source separation system. The research recommends which criteria can be improved on in order to achieve a well functioning source separation system.

Executive Summary

Many communities in remote polar areas are facing a transition towards modern life, involving new standards of living, as well as having access to the goods associated with living in modern cities. However, while the transition is happening rapidly on a material and cultural level thanks to communication and media, the infrastructure is not keeping pace.

With the increase of material supply, and adoption of mainstream consumption patterns, a growing amount of waste to be handled is becoming a problem. Not only for the infrastructure, but also for the pristine environment found in these remote areas. The shorter food chains, with more vulnerable ecosystems calls for action when it comes to handling the waste generated by these communities. This is recognised by the world community and the countries on the northern hemisphere, which in turn has resulted in several ratified agreements and conventions, with the purpose to protect the marine ecosystems associated with these communities.

Historically the waste management in the polar communities has moved from throwing the waste out of the window to landfills. However, with the slow biodegradation and rapid filling up of landfills, as well as leachate from landfills polluting the fragile marine ecosystems, new policies calls for developing the infrastructure on handling the waste.

Longyearbyen is a community in Svalbard, an island group north of Norway. The island group under Norwegian sovereignty introduced source separation in 1993. The aim is to develop the system further to even recycle organic waste. Composting is here considered a possible solution. Traditionally the introduction of compost in communities as a way to handle organic waste from enterprises and households has been more oriented towards the actual composting facilities. However, without a functioning source separation there is not much hope for achieving good quality compost. The quality of compost is important since this decides its use on the aftermarket. In the worst case compost could actually result in introducing a pollutant to nature, should it contain pesticides or heavy metals.

This thesis focuses on the quality aspects of the source separation system. By examining the system through a model developed in 1993 at Chalmers, we examine a number of factors influencing on the quality aspects of the system. Through this examination we are able to conclude on the present situation of the system, and also what challenges must be met in order to ensure a well functioning system. The model has also been compared through literature review on factors influencing on behaviour that support recycling, in order to verify the models validity.

The examined criteria influencing on the quality aspects was opinion climate, status of source separation system in the selected area, level of information in connection with introduction and operation, the use of incentives, household population and type of building, practical design of source separation system and distance to waste containers. The criteria were used as a framework to analyse the characteristics of Longyearbyen, and then a prediction of the quality aspects could be made. For some of the aspects the predictions could be verified against previously made surveys.

The quality aspects associated with these criteria are participation level, outcome of sorted waste, level of wrong sorted waste, environmental consequence, the systems user satisfaction, the systems ability to generate understanding for the necessity of recycling.

For Longyearbyen the opinion climate, or actuality of the issue in the local available media, was characterised by a low presence and actuality. The status of the source separation system

in Longyearbyen could be described as a system under development. The level of information in connection with introduction and operation was through a brochure defining different fractions. The use of incentives in the form of differentiated tax or supplied equipment to the household was not present in Longyearbyen. The household population could be described as less established households, where 70% of the households consist of one person. The type of buildings is predominantly multiple rental apartment houses, owned 90% by the Norwegian state. Characteristic for the buildings are that they are low houses with 2-3 floors, with a majority suitable for only one person. The practical design and layout of the source separation is characterised by a source separation system designed for paper, glass and aluminium. These fractions are recycled. The rest goes to the local landfill. The households themselves are responsible for making the necessary arrangement for sorting into the existing fractions. The number of containers used for disposal of the sorted waste as well as residual waste allows for a short walking distance for disposing.

By combining the strength of each of the criteria and presumed connection with the quality aspects, an estimate on the outcome of the quality aspects was made trough a model. The participation level is mainly depending on opinion climate, status of the source separation system, information, type of household population and housing type. Based on the examined criteria, we could expect the participation level to be towards low.

The sorting outcome, or how large share of the possible amount goes to the right fraction, was dependent on participation level as well as the households conditions to sort correctly and consequently. Here the sorting outcome, based on the findings could be expected to be towards low. The level of wrong-sorted waste was partly dependent on the share of non-participants, as well as the quality of the sorting instructions, and to what extent the fraction definition is understandable and logical for the source separation system. The definitions were found to be clear, but factors like housing type and low social control and ditto participation level leads us to expect a high level of wrong-sorted waste.

The environmental consequence is dependent on the use of incentives, availability of sorting equipment, housing type and the definitions of fractions. Based on the findings we could expect a high level of fractions of harmful consequence for the environment. The systems user satisfaction is related to available information, incitements, sorting equipment, type of household population and distance to disposal of waste. Here the systems user satisfaction could be expected to be low. The last quality aspect, the systems ability to generate understanding for the necessity of recycling, is dependent on opinion climate, information, household population and clear definitions of fractions. Here we could expect the understanding of the closed loop principle to be low.

The main criteria influencing on the quality aspects are low social control due to mostly single household in multiple apartment housing. The source separation system is not fully developed. Further, the level of participation is low. There are no incentives for source separation as well as no available standard sorting equipment in the kitchens. Lastly there is no present public opinion in the media regarding environmental issues.

Only one of the above criteria, housing type, is constant. The remaining criteria can be improved on. Since each quality aspect is influenced by a set of criteria, we are able to move towards a positively influencing majority of criteria on each aspect. With a positive result of each quality aspect we will obtain the indication of a well functioning source separation system. This is a necessity for the introduction of composting as a way of handling organic waste from household and enterprises in Longyearbyen.

The recommendation for Longyearbyen to follow in order to have a well functioning source separation system is to continue to develop the source separation system, communicating the long-term goals to its users. Continue to inform the public trough motivating information and instructions and attitudinal altering campaigns increasing the level of environmental awareness and understanding of the existing source separation system. Longyearbyen should also install sorting equipment in the kitchen to facilitate the sorting of waste into fractions and introduce incitements in the form of fees mirroring the amount of waste delivered from the households.

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1. Introduction

1.1 Introduction to thesis idea

This thesis was written as a mandatory requirement for the Master of Science program in Environmental Management and Policy, at the International Institute of Industrial Environmental Economics at Lund University.

1.2 Background to thesis idea

Longyearbyen, a small town of 1300 citizens situated at Svalbard in the arctic regions, has similar to other settlements in polar regions made the transition to modern life and infrastructure. With a better standard of living with ample supplies from the mainland of Norway, the production of waste has increased amounting to two and half the amount produced per capita on mainland Norway, and the landfill is filling up rapidly.[1] This calls for new solutions. Previously all waste was dumped at the local landfill, but since 1993 source separation has been introduced in Longyearbyen[2]. The fractions, paper, glass and rest are sorted out and recycled. However the rest fraction, there among organic household waste, are compressed and dumped at the landfill[3]. A problem in the arctic regions is that all organic substance tends to break down very slowly. Another problem is that there is no vegetation like forest that could hide a landfill. The prestine environment with unique fauna and animal species are also influenced by the landfill. The marine ecosystems with their short nutritional chains are especially sensitive to pollution, like for example leachate of organic matter in the landfill including heavy metals and pesticides.[4]

By Norwegian law[5], it is prohibited since 1999 to dump organic waste at landfills. However, this is only a recommendation for the Svalbard region so far. Still, according to the waste management plan for Longyearbyen, the plan is to develop the source separation systems to even include organic fractions, allowing for the possibility of organic treatment and thus a closed loop approach to organic matter[6]. A test project performed in Longyearbyen in 1974 showed that organic decomposition will take place spontaneously in an open stack, showing that even settlements in extreme polar regions like Svalbard allow for composting. However, the rate of decomposition was half of that on the Norwegian mainland mainly because of the low temperature[7]. However, today the methods and facilities available for composting allows for controlling parameters critical to the decomposing process like temperature, humidity and oxygen, allowing for a rapid and controlled process thus securing an even decomposition. However, the issue of quality is more than an even decomposition. The fact that compost allows for a great volume reduction of the organic waste, up to 80%, also allows for a concentration of pesticides and heavy metals. It is therefore important to have a functioning

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[1] Avfall og avfallshantering på Svalbard-Status og forslag til tiltak. Sysselmanens rapportserie Nr.2/1998, p 34

[2] Ibid. p 35

[3] Ibid. p 35

[4] Lov om Miljövärn på Svalbard. Norges Offentlige utredninger 1999:21. p 34

[5] Ibid., p.26

[6] Avfallsplan for Longyearbyen. Svalbard Samfunnsdrift. February 2000. p 5

[7] Avfall på Svalbard. Grovkomposteringsforsök i Ny-Ålesund. Rapport Nr. STF 21 78035, p 18

source separation in order to avoid the introduction of pesticides and heavy metals to the organic fractions.

1.3 Purpose of the thesis

The purpose of this thesis is to find out whether composting of organic household waste is a suitable method for waste management in Longyearbyen on Svalbard. In order to know this we need to estimate what quality can be expected of the decomposed organic fraction from household waste in Longyearbyen. In addition to a functioning composting process, the quality of the compost is also dependent on the function of the source separation system. In this thesis a set of criteria that on an experiential basis is connected to quality requirements will be examined. From the examined criteria a set of assumptions can be formed regarding the quality of the compost[8]. This in turn will give a possible answer to whether the present situation allows for an introduction of composting as a meaningful replacement for the present solution i.e. using the landfill. The examined criteria will also lead to recommendations, in order to know what needs to be done in order to have a well functioning source separation system.

1.4 Scope and limitations

If I would be asked whether composting would be the solution for Longyearbyen, a town in the arctic regions of the world, with people carrying arms for protecting themselves against polar bears, I would be faced with several questions. From a system perspective composting actually consists of several steps. First source separation, then collection, then the actual decomposition of the organic matter and then finally the aftermarket for the final product. The obvious question is whether you can you make compost in the arctic regions or not? Or more precisely, can the necessary parameters for decomposition to take place be fulfilled? Further, what aftermarket can be expected for compost with none of the traditional channels available, i.e. farming, gardening?

Regarding the decomposition process an arctic settlement like Longyearbyen offers special climatic conditions. However, today's composting technology allows for the necessary parameters to be controlled and fulfilled[9]. Further, the issue of aftermarket is dependent on the quality of the compost. More precisely, what content of heavy metals and pesticides will the final product contain? The level of purity of the compost decides its use, i.e. what the relevant aftermarket is. The level of purity of the compost is dependent on a functioning source separation system.

The focus of this thesis is therefore on the source separation system and what level of functioning can be expected in Longyearbyen. With a functioning source separation system a pure organic fraction can be expected from it, thus avoiding the introduction of heavy metals and pesticides i.e. creating a new pollution source.

From an economic point of view one could compare the cost of a composting approach with that of the traditional landfill. However, the landfill approach is not a solution, since it is not recommended for Longyearbyen to dump the organic fraction at the landfill in the future.

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[8] Naturvårdsverket, Rapport 4191, *Beskrivning av sex olika system för källsortering av hushållsavfall,* p. 9

[9] Vafab, Huvudrapport 1996, *Källsortering och biologisk avfallsbehandling i vafab-regionen*, p. 113

One alternative to composting is making biogas from the organic fraction. Still one is faced with the fact that this process leaves a residual fraction, which must be recycled back to nature. The issue on heavy metals and pesticides is relevant even here. Thus the focus on the source separation system.

1.5 Outline of the thesis

The thesis is divided into the following sections.

In the first part we start by linking composting to pollution prevention, followed by a general description of source separation and composting principles.

In the second part the reader is introduced to a set of general criteria and quality issues related to source. Here we also find a literature review on factors influencing behaviour that support recycling.

In the third part a description of the waste management system in Longyearbyen is given.

In the fourth part the quality related criteria for source separation are examined for the population at Longyearbyen in Svalbard.

In the fifth part we form assumptions regarding the possible quality outcome of the source separation system based on the examination of the criteria described in part three.

In part six we discuss the assumptions and what this implicates for a possible introduction of composting at Longyearbyen in Svalbard. This is followed by recommendations based on the outcome of the discussion.

2. Composting

2.1 Composting and its relation to pollution prevention

The U.S. Pollution and Prevention Act of 1990 defines pollution prevention, PP, as any practice consistent with the following description:

"Reduces the amount of hazardous substance, pollution or contaminant entering any waste stream or otherwise released into the environment (includes fugitive emissions) prior to recycling, treatment or disposal; and reduces the hazard to public health and the environment associated with the release of such substances, pollution or contaminants"[10].

Traditional waste management sees waste as an unavoidable product of economic growth and then attempts to manage wastes in ways that will reduce environmental harm-mostly by burning or burying them. Thus this can be understood as a *high waste approach.*

Preventing pollution and waste can be understood as a *low waste approach* that views most solid and hazardous waste as potential resources that we should be recycling, composting, reusing, or not using in the first place.

According to the U.S. National Academy of Sciences, the *low waste approach* should have the following hierarchy of goals:

1) *Reduce* waste and pollution

2) *Reuse* as many things as possible

3) *Recycle and compost* as much waste as possible

4) *Chemically or biologically treat or incinerate* waste that can't be reduced

5) *Bury* what is left in state-of -the -art landfills or aboveground vaults after the first four goals have been met

This could be illustrated as in the following figure:

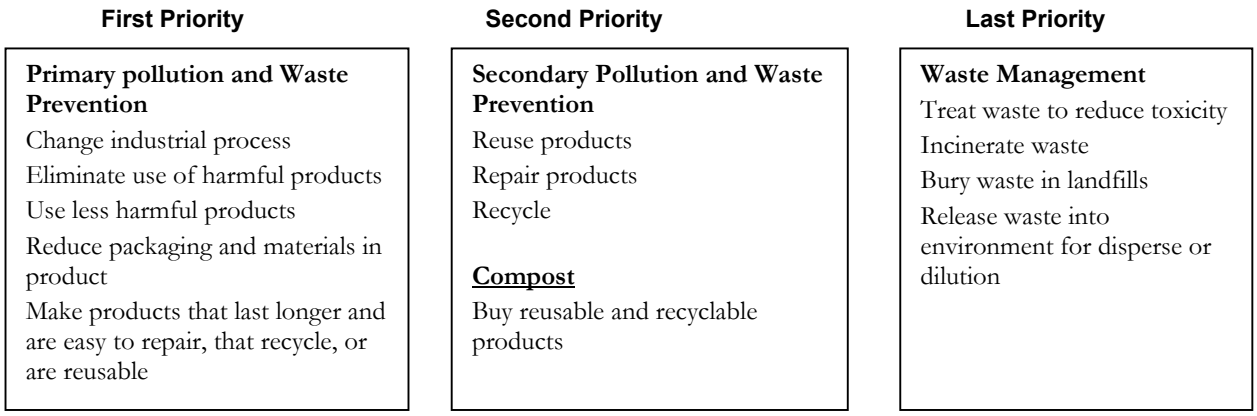

Figure 1 Low waste approach hierarchy
Source: Miller, Nature and Environment

[10] Industrial Pollution Prevention Handbook, Harry M. Freeman. Mc Graw Hill 1995

As opposed to traditional waste management of organic household waste, composting prevents the emission of nutritional salts and organic material into surface and groundwater as well as the leakage of methane into the atmosphere. Further, composting allows for good housekeeping with organic material and plant nutrition.

The problems with leachate from waste dumps are commonly well known. The level of nitrogen and oxygen consuming substances can be significant. The level of pollutants in the form of heavy metals and chemical substances can also be of great concern.

The requirements set from waste water treatment plants on the accepted level of pollution in the leachate from the waste dump often implicates that the leachate is not accepted in the waste water treatment plants. Thus the leachate must be treated locally in order to prevent the pollution of recipients and groundwater since municipal wastewater treatment plants cannot be used.

Good housekeeping with plant nutrition is mainly concerned with phosphorus, which in a long-term perspective can become a scarce resource. In a waste dump the nutrition is difficult to access. Further, humus is of importance to farming.

Reintroducing organic waste, through biological treatment, to some form of farming system/activity implicates that valuable nutrition and organic material can be a part of the natural loop.

Biological treatment of waste is using nature's own method of transforming, or decomposing, organic material and aims to release the fertilising agents of the waste. In nature the decomposition takes place in both aerobe (i.e. the process takes place in the presence of oxygen), also referred to as composting, or in anaerobe, oxygen depleted environment, referred to as bio gasification. However we are limiting ourselves to composting in this thesis.

2.2 Collection of organic household waste

Collection of organic household waste happens in several steps. To start with the waste is temporarily stored in containers in the kitchen, thereafter the waste is transferred to collection containers and then finally collected by a vehicle for transport to treatment. To achieve high quality compost the organic household waste should be collected separately from other waste.[11]

2.2.1 Principles for ventilated/open and closed storing in households

A number of different variations on containers exist for household waste on the market. The equipment used spans from simple holders for plastic or paper bags to sophisticated solutions with plastic containers.[12]

[11] Vafab, Huvudrapport 1996, *Källsortering och biologisk avfallsbehandling i vafab-regionen,* p 21

[12] Ibid., p 24

2.2.1.1 Source separation

With source separation you understand that the producer of the waste does not mix residual products with other sorted fractions. This means that reusable material like glass, paper, packaging material and hazardous material is not mixed with other waste. In a more extensive source separation even organic waste material is separated from the rest of the waste. This means that the different types of waste material is kept separated from each other from beginning in the household, during collection of the waste and reuse or treatment of the waste.

It is important to stress that source separation is a prerequisite for separating the different waste streams according to their different qualities.

Source separation is an approach for channelling waste streams with different material qualities strive for the appropriate treatment. However, it should not be seen as the universal method to the waste problem. For reduction of waste, it is important to prevent the upcoming of waste at the source and good housekeeping. The separate handling of the waste increases the possibilities for material reuse, environmentally correct treatment of hazardous waste and the production of high quality compost. Also source separation serves to decrease or prevent uncontrolled emissions from landfills. In order to motivate source separation, it is necessary that the material can be finally handled in a meaningful way.

2.2.1.2 Goals of source separation

The main goal of source separation is to contribute to a decrease in the amount of waste created, better housekeeping and to a general improvement for the environment regarding the management of waste. The sorted material needs to be of use and in the case of final treatment or deposition it needs to be performed in a least harmful way for the environment.[13]

A system solution for the separation of waste can be as follows:

[13] Ibid., p 22

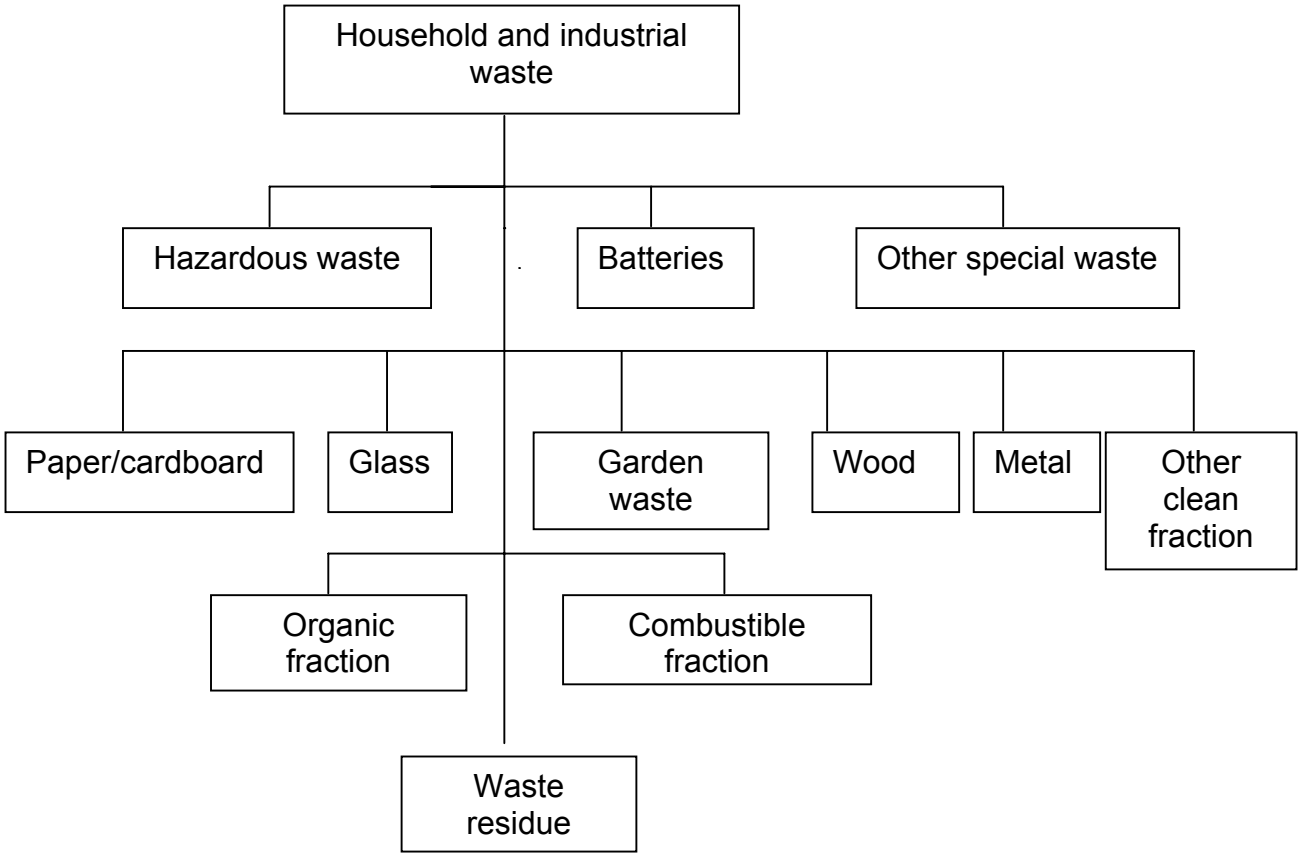

Figure 2 A system solution for the separation of waste

Depending on the quality of the different sorted materials, three different goals for source separation can be identified.[14]

- Source separation in order to decrease the hazardousness of the waste
- Source separation to decrease the amount of waste
- Source separation to improve waste treatment

2.2.1.3 Source separation in order to decrease the hazardousness of the waste

In source separation for decreasing the hazardousness of the waste, hazardous waste, batteries and other harmful waste is sorted out and treated separately. This increases the purity of the material that should be reused or treated.[15]

[14] Ibid., p 17

[15] Ibid.

2.2.1.4 Source separation for decreasing the amount of waste

This means sorting out pure material that can be reused or used for other purposes. Here we find material that can be used again as raw material (paper, glass, packaging material and metal). Also we find fractions to be used for combustion from industry and the construction activities. The sorting out of pure material fraction requires that a meaningful use for the material can be found and that there exists a market for this material. Alternatively, a market could be created [16]

2.2.1.5 Source separation in order to improve waste treatment

By sorting the waste into fractions depending on their material quality the treatment of the waste can be performed in manner that is adequate with respect to the environment and that leads to good housekeeping with resources. According to the Swedish EPA long term considerations should be prioritised with respect to resources as well as efforts to minimise the effect on the environment as far as technically and economically possible. This means that reintroducing material to nature by for example composting should be prioritised before using the energy content of the waste material if this can be done in a way that is environmentally sound and economically possible.[17]

It is the Swedish EPA view that after the hazardous waste and pure material that can reused are sorted out, the remaining waste should be separated into three fractions. One fraction that is easy decomposable, one combustible fraction and finally the remaining fraction should go to landfill.[18]

In Sweden today household waste is mainly treated through incineration or dumping at landfills. Only a small fraction is treated biologically. This is organic waste coming from garden waste and from unsorted household waste mechanically separated into an organic fraction. Figure 2 shows the relationship between different methods of waste treatment in Sweden today. [19]

With source separation you allow for this relationship to be altered. As previously mentioned the goal of source separation is better housekeeping, decreased amount of waste and from an environmental point of view better treatment of the waste. By handling and destructing environmental hazardous waste separately, sorting out what can be directly reused (paper, glass and other packaging material) and sorting out and biologically treat organic household waste hypothetically you can expect where all waste is sorted according to the strategy shown in figure, we can expect the following relationship between different types of waste.

[16] Ibid.

[17] Ibid.

[18] Ibid.

[19] Ibid.

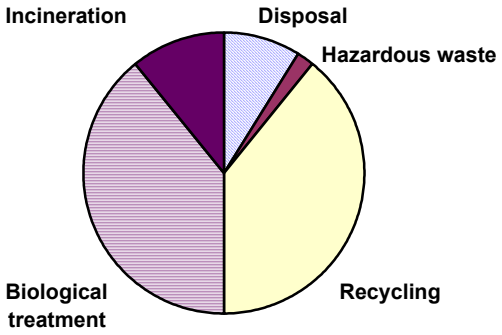

Figure 3 Ways of treating waste in a system based on far going source separation

Source: Vafab, Huvudrapport 1996, Källsortering och biologisk avfallsbehandling i vafab-regionen, p 22

Figure 3 is based on ideal conditions and thus is the theoretical potential for a decrease in the need of incineration and need of dumping at landfills and a maximum of the amount of waste being reused and biologically treated. It is also important to point out that a more extensive source separation allows for an improvement of the quality of the composted (biologically treated organic fraction of the household waste). This because the organic fraction is not contaminated with other material by being mixed with other waste fractions. The result of using mechanical separation of household waste compared with sorted household waste in terms of content of heavy metals can be displayed in the following table.

Table 1 Result of using mechanical separation of household waste compared with sorted household waste in terms of content of heavy metals.

	Mechanically separated material	Source separated material from Borlänge	Source separated material from Skultuna
Chrome	40.6	9	<5
Nickel	41.6	6	<2
Lead	522.2	12	<5
Cadmium	3.7	0.24	<0.1
Mercury	3.5	0.11	0.19

Source Vafab, Huvudrapport 1996, Källsortering och biologisk avfallsbehandling i vafab-regionen, p.23

Table 1 shows that heavy metals in the organic fraction can be significantly lowered by extensive source separation. Thus the extensive source separation improves the conditions for the contents of nutrition and humus in the compost to be reintroduced into the natural biological circle in nature.[20]

[20] Ibid., p 23

2.2.2 The role of the households

Essential for the source separation to work is the households' motivation and environmental awareness. A general experience from studies of source separation in households in Sweden all shows that the environmental awareness regarding the need for improvement of the waste management is necessary, both for the reason of good housekeeping and for the environment. This in turn makes the introduction of more far going source separation, which is necessary when it comes to bioremediation of organic waste, less problematic.

There are different types of households and this influences the degree of source separation to be expected. In house areas with single households, you can expect a generally higher motivation and commitment for source separation, both to the degree of participation and the quality on the sorted fractions. In areas with multiple apartments housing the type of household allows for a more anonymous way of living and the personal commitment, which is a condition for a well functioning source separation, is less easily obtained than in areas with separate households. [21]

Of importance is also that the solutions for source separation offered to the households need to be *comfortable in handling, offer a hygienic use and are simple in function.* Further, it is also necessary that the households are instructed, motivated and encouraged. In summary, a well-designed source separation system together with appropriate information could lead to that a majority of the households will participate in the source separation and that it could be expected to function correctly.

In summary the following criteria should be fulfilled when designing a system for source separation:

- The amount of work needed from the households should be acceptable and the separation easy to be performed. Thus more households would like to participate and follow the instructions.

- The motives for the source separation need to be clarified and easy to understand.

- The instructions need to be simple and if possible linked to environmental, recycling and remediation targets. If necessary the information should be available in different languages.

- The sorted fractions need to be of satisfying quality in order to have an after market.

- The working environment for the workers as well as for the household need to be considered

- The costs should be motivated from an environmental and housekeeping point of view.

[21] Ibid., p 144

2.3 Composting

In composting mainly heat, carbon dioxide and water are produced as well as humus and a nutritional rest referred to as compost. Important parameters for the process of decomposing are the energy content of the material, pH, as well as the content of carbon, nitrogen, phosphorus and water. To speed up the process of the decomposition it is important to maintain the content of water, oxygen, porosity as well as the balance between carbon/nitrogen and carbon/phosphorus. In order to increase the surface for the microorganisms to work on shredding of the material can be done. A higher specific surface of the organic particle influences the speed of decomposing positively.

Important for the decomposition is the temperature. Higher temperature will accelerate the chemical processes and also influence on the selection of micro organisms present in the process. At temperatures between 20 to 40° C the metabolism increases rapidly. Normally the fastest decomposing takes place in the temperature interval of 50-60° C. However, if the temperature rises above 60°, many organisms will start to die, overheating results in drastic population fluctuations and possibly unpleasant odours, as the compost pile sterilizes itself and micro organisms die.

The process of decomposing is also dependent of the water content. Micro-organisms need water to maintain their metabolic activity. Nutrition is transported via water. If the water content is too high porosity decreases resulting in less access to oxygen. Ideally the moisture content should be between 55-70%.

Composting is an aerobic process, which means it occurs in the presence of oxygen. When a pile receives too little oxygen, parts of it can become anaerobic, and offensive odours can result. A level of 15-20% of oxygen is favourable for the microbiological activity. Levels of 12-14% can result in lack of oxygen for an optimised decomposing. 5-10% is the limit for aerobic process. Below 2% we are talking about an anaerobic process. Forced aeration is sometimes applied to supply oxygen to avoid an anaerobe environment.

Carbon and nitrogen are the primary elements that organisms need to live. Bacteria and fungi get their energy from carbon, found in carbohydrates such as the cellulose in wood chips or leaves. Nitrogen, a component of protein, is necessary to support a large population of these beneficial microorganisms. The ideal ratio of these elements for composting is 30 parts carbon to one part nitrogen. If the C/N ratio is too low a surplus of nitrogen could be released in the form of ammonia. If the C/N ratio is too high the decomposition will slow down due to lack of nitrogen for the microorganisms.

The C/N ratio for household organic waste is approximately. 17-23 to 1. By blending different materials, it is possible to improve the balance of carbon and nitrogen and hasten decomposition. Leaves usually have 40-80 parts carbon to nitrogen. Grass clippings, in contrast, have high levels of nitrogen. Blending waste materials to balance nutriment for the micro organism's results in faster composting with less potential for odour problems.

Sorted organic waste from household normally has a pH-level approximately around 6 or less. In Sweden the experience is that the pH-level could drop to 5.0-5.5 and sometimes even lower. This is probably because of large amounts of citric fruits consumed during winter. In the initiation of the decomposition the process can take place at pH-levels around 6 without any problems occurring. Lower pH-levels can delay and even obstruct the decomposition.

During the decomposition the pH-level increases and then in the mature phase to stabilise around 7.5-8.0.[22]

2.3.1 Technologies for open central composting

Open composting means that the decomposition takes place uncovered or under a roof. The compost pile is under both conditions exposed to natural changes in temperature and wind due to fluctuations in the weather conditions. When the compost pile is situated under a roof it is protected from rain.

The process of decomposition in open composting can happen through the turned windrow, madras or surface composting. Of these three methods the turned windrow method is the most commonly used.

The turned windrow method is most commonly used for rapid composting of yard wastes. Windrows are constructed to be 1-3 metres high, 3-6 metres wide with a length appropriate for the site. Windrows are aerated regularly through physical movement, or air is drawn or blown by exhaust fans or small blowers through a network of perforated plastic pipes under the windrows. The physical movement can be done through using a front - end loader or other specialised turning equipment to provide good aeration and temperature control.

In the madras pile method, the material for composting is put in piles of 2-3,5 metres thickness. Physical mixing and turning provide oxygen by a front-end loader 1-2 times a year.

Surface composting means that the raw compost is put in thin layers on the ground. This technique demands a lot of surface and is highly influenced by precipitation and variations in temperature.[23]

2.3.2 Techniques for in-vessel systems

A number of in-vessel systems are available commercially. In-vessel composting means that the complete process of decomposition or parts of it happens in a closed container, often with built in aeration and mechanical mixing equipment. The in-vessel approach makes it possible to monitor the key parameters of the process of decomposition. The parameters monitored are temperature, humidity and level of oxygen. A large number of in-vessel systems have been developed during the last years.[24]

- Drum composting
- Box composting
- Tunnel composting
- Container composting
- Tower composting
- Closed hall composting

[22] Vafab, Huvudrapport 1996, *Källsortering och biologisk avfallsbehandling i vafab-regionen,* p 72-75

[23] Ibid., p 110

[24] Ibid., p 113-114

Drum composting means that composting happens in a mechanical aerated drum rotating in cycles or continually. The drums are usually isolated and the speed of rotation in some cases can be varied. Smaller drums are made of plastic and larger of steel. The compost is fed forward by fins inside and the rotation of the drum and sometimes an inclination.[25]

Tunnel composting takes place in long narrow channels with roof, situated inside a building. Aeration of the material happens through a network of channels under the channels and eventually by ventilating the air in the channels. The composting can happen either continuously or in batches.[26]

Tower composting involves decomposition of organic waste in a vertical standing cylinders. Turnover of the material is performed by screws mounted vertically or horizontally. Aeration happens from the floor of the vertical cylinder.[27]

Box composting involves decomposition in boxes, normally without roofs, situated in a ventilated building. Aeration happens partly from underneath the composting material and partly through mixing of the material with transport screws. Normally the decomposition happens in batches and the method is very flexible in handling different types of different material.[28]

Container composting is decomposition in a closed steel container of larger format, 10-35m^3 prepared for aeration and for the possibility of controlling certain key parameters. The container can be connected to other containers forming an aeration system. The containers can also be stacked vertically up to four layers in order to save area space in case of large incoming amounts of material. The decomposition happens in batches.[29]

Closed hall composting means that the decomposition happens in a closed building. The walls and roof of the building is insulated and the aeration happens through a network of channels in the floor. The ventilated air is usually filtered to avoid odour. The material is mixed automatically with technical equipment that slowly moves the material from the intake to the outlet.[30]

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[25] Ibid.

[26] Ibid., p 118

[27] Ibid., p 118

[28] Ibid., p 114

[29] Ibid.

[30] Ibid., p 119

3. Criteria and quality related aspects of a source separation system

A well functioning system is crucial when one wants to introduce for example composting as a way of handling organic waste. Without pure fractions, especially regarding the organic fraction, a new polluting source is introduced. Also regarding the investment made in the source separating facilities and composting equipment, it would seem meaningless if one could not expect a high rate of participation. So from here we move into describing a model that could be used for evaluating and improving the source separating system at Longyearbyen in Svalbard.

If we agree that in order to use compost as a way of handling organic waste we need a functioning source separation system, then there should be certain quality aspects fulfilled by the system. One way to evaluate the function of the system is to perform a field study regarding different chosen quality aspects or indicators. However, not always statistical info is readily available. Even if we do not know how well the function of a system is, we know how the system is designed in terms of equipment, statistics on types of housing and so on. What could be of great use then is a model based on experiential connections between what is held to be important criteria for a well functioning system and how these criteria influence different quality indicators. We can in other words use theory for estimating the outcome of different quality indicators for a studied source separation system. Further we can then use knowledge from studies to see what need to be changed or improved of the different criteria of the system in question in order to improve on the quality indicators. We can use theory to gain understanding on what influence the performance of a system and give focus to what efforts are necessary for improving on the situation

An interesting point here is that on a phone interview made with Vigdis Hole 2005-01-13, head of physical planning at Longyearbyen, she verified that the level of participation was very low. In fact 23% as compared to the mainland averaging 40-60%. No examination was made regarding the functioning of the source separation system, except the low level of participation. Further, she could not really explain why the participation was this low, though she had some ideas about it.

What follows is an introduction of the systems model, starting with a description of its criteria. The description of the model, is based on the report by Svenska Renhållsverks-Föreningen, RVF 1993, "Beskrivning av sex olika system för källsortering av hushållsavfall".

3.1 A description of local criteria for source separation system influencing the quality of the organic waste fraction

In evaluating a number of source separation systems in different communities in Sweden, a hypothesis was proposed by Konsumenteknik, Chalmers on the connection between the existing local criteria of the source separation system and the quality of the sorted fractions. The work was based on the project "Composting and incineration of organic and combustible fraction of household waste" The project was founded by the Swedish EPA and several Swedish communities. The Swedish RVF was also involved in the project along with Lund University.

The selection of the factors was based on the experience from previous studies on what would influence on the quality of the source separation in households.[31]

Six factors seems on an experiential basis to be of significant when it comes to influencing on the households source separation and the quality of the sorted waste. [32]

- Opinion climate
- Status of source separation in the selected area
- Level of information in connection with introduction and operation
- The use of incentives
- Household population and type of building
- Practical design of source separation system and distance to waste containers

3.1.1 Opinion climate

By this is meant the actuality of the issue, i.e. presence of the issue in the local available media. A present and active debate on environmental issues in local media strengthens the household motivation and understanding for the necessity of source separation and the understanding of the connection between the effect of the households waste production and its influence on the ecosystems.[33]

Three levels are stated:

3 significant presence and actuality

2 some presence and actuality

1 low presence and actuality

3.1.2 Status of source separation in the selected area

The organiser of the source separation systems communicated intensions and long-term commitment, this influence the project's credibility with the households.

A source separation project can be on a short-term trial basis for a small selected group or on an all-encompassing permanent basis. A thoroughly planned and introduced mandatory (obligatory) source separation system is more likely to succeed than a small scale, short term test project, even though this could as well have been well planned.

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[31] Svenska Renhållningsverks-Föreningen RVF 1993, *Beskrivning av sex olika system för källsortering av hushållsavfall*, p 73

[32] Ibid., p 74

[33] Ibid., p 74

Evaluating a source separation system, it is also important to remember that source separation of recyclable and organic waste most often are made in parallell, but at the same time separate systems. [34]

The classification of the source separation system can be made into three categories:

V An activity, encompassing all, of long term, not to be revaluated, part of an ongoing development

T On trial basis, not encompassing all, an "island" existing in another system, often of small size with a definitive aim to be re-evaluated. The purpose is to gain experience.

D The activity is under development.

3.1.3 Level of information in connection with introduction and operation

Two types of information can strengthen the system. The first one is motivating information. Here you find feedback, information on progress or result, mass information, newspapers, radio and TV, campaigns. Instructional information can be in the form of separate magazine, mass meeting, brochures, and directed information.[35]

3.1.4 The use of incentives

In connection with information, incentives can be used to increase motivation and response among the households in using the source separation system. However studies have shown (p 75) that incentives play a marginal effect, if the introduction of the system is done on a serious and credible manner in dealing with the households. On the other hand incentives, in the form of lower taxes (T) or issued source separation equipment (E), can be a token of sincerity and respect for the households role in the system.[36]

3.1.5 Household population and type of buildings

The commitment, attitude and loyalty towards using the source separation system can vary depending on type of household and population. A house hold can be consisting of one family in a villa or row house, or of families or singles living in apartment buildings, the last being typical for Longyearbyen.[37]

3.1.6 Practical layout and design of the source separating system

Types of fractions chosen and distance to disposal are of importance. The equipment should be practical and pedagogic in use. As previously mentioned, recyclable and organic

[34] Ibid., p 75

[35] Ibid.

[36] Ibid., p 75

[37] Ibid.

household waste can be sorted in two separate but parallel processes. Of interest here is the percentage of the fraction correctly sorted.[38]

Also the distance to the disposal of the sorted fraction is of relevance.

There are four classes used:

O: In the immediate connection to the household.

1: Minor walking distance, without overcoat, less than 50 metres

2: Great walking distance, with overcoat, 50-500 metres

3: Vehicle distance, vehicle have to be used, 500 metres or more

3.2 Quality aspects of a source separation system

The initial criteria described above are assumed to have an influence on different quality aspects of a source separation system. There are a number of different quality aspects regarding a source separation system. [39]

3.2.1 Level of participation

How large share of the habitants are participating in the source separation system. There has been documented a difference in participation between one family and several family houses. To measure the participation in several family houses is more difficult.

The level of participation is of importance when it comes to outcome of sorted waste. Those who do not participate may because of inconsistent sorting, passiveness or simply objection to the system lower the outcome of sorted waste and even increase the level of wrong-sorted waste. This again influence on the quality of the compost.[40]

3.2.2 Outcome of sorting

How large share of the possible amount goes to the right fraction.[41]

3.2.3 Level of wrong sorted waste

How large share of wrongly sorted material is contained in a fraction.[42]

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[38] Ibid., p 76

[39] Ibid., p 77

[40] Ibid.

[41] Ibid.

[42] Ibid

3.2.4 Environmental consequence

What levels of environmental hazardous substances exists in the organic fraction. This can be found through laboratory analysis of the composted material[43]

3.2.5 The systems user satisfaction

This is critical for the long-term survival of the source separation system.[44]

3.2.6 The systems ability to generate understanding for the necessity of recycling

Even this is of importance for the long-term survival of the system. However, this quality aspect is difficult to measure or quantify.[45]

[43] Ibid., p 78

[44] Ibid.

[45] Ibid.

4. Factors influencing behaviours that support recycling, a literature review

In the previous chapter we described the components of a possible model for estimating the outcome with regards to certain quality indicators for a source separation system. This was based on a project performed in 1993 by Konsumenteknik, Chalmers in Sweden. Now, years have passed since this project was ended. A good question then is whether anything has changed since 1993 in terms of factors influencing on what makes people recycle and source separate. In summary, the criteria of the model that would influence on the quality indicators was:

- Opinion climate
- Status of source separation in the selected area
- Level of information in connection with introduction and drift
- The use of incentives
- Household population and type of building
- Practical design of source separation system and distance to waste containers

Following is an examination of literature regarding factors that support recycling.

Most people think that recycling and source separation is important and necessary, but for many recycling and source separation is drudgery, especially when compared to discarding an item as trash. Many state that inconvenience and lack of time are reasons for not recycling (Vinig and Ebreo, 1990, Gamba and Oskamp, 1994, McCary & Shrum 1994).

In designing a system for recycling on a municipal level, you obviously want to design it in a way that as many as possible would want to use it. The question is then, what makes people want to participate, what are the motivating factors?

4.1 Information

Information and education can change attitudes and beliefs, but that many barriers, both within individuals and in their social and economic environment, can keep proenvironmental attitudes from being expressed in action. However, the best information campaigns cannot overcome external barriers to action, such as financial expense or serious inconvenience.[46]

Recycling can be a complex task, since there are multiple fractions to sort household waste into. Here education and information is important. Not knowing where to put what can be an obstacle for consumers, even if they are in favour of an environmentally sound behaviour[47]. Sources of information could be the pamphlets that reach the households meant

[46] Gardner, G., Stern, P. (2003). Environmental problems and human behavior. p 74

[47] Tanner, C. (1999). Constraints on environmental behaviour. Journal of environmental psychology. 19, p 145-157

as instruction for the use of the recycling system. Also news media can supply information. Here overall plans for the communities waste management and policies can be communicated. The frequency in which news on environmental issues and recycling also reflects on the actuality of the issue, giving the end user an orientation what is happening on the community level, through understanding more about the reasons and plans for recycling. Social orientation is a reason for persisting in recycling. Perceiving one self as a part of community, being proud to recycle, having friends, neighbours, news media that encourage recycling.[48]

4.2 Economic incentives

Depending on the amount of waste disposed, a weight-based fee can be used to influence on the amount of disposed waste, and motivating people to recycle more. In this way less amount of waste needs to be collected by the municipality.

Economic incentives were according to B. F. Skinner an effective way of influencing on people's environmental behaviour. He suggested that humans are, in essence, genetically programmed to destroy the environment. Skinner argued that humans are short-term egoists by nature, meaning that people's behaviour is determined mainly by immediate personal consequence, rather than long-term consequences or its consequences for others. During humanities evolution this behaviour was a necessity, however, given the size of the human population in our time, this behaviour is maladaptive. Human short-term egoism makes incentives the only effective strategy for solving environmental problems.[49]

However, the issue on economic incentives is not as straightforward as can be expected, even though most people are positive towards it. It is of a more complex nature according to Åberg.[50] A Danish study showed that people were in favour of weight-based fees and agreed to that it was both effective and equitable. Peoples attitudes towards the fee system were also influenced by their beliefs in how effective the system was. The opportunity for a personal benefit also influenced the attitude towards the billing system. However, the study concluded that economic incentives did not prove to be effective on minimising generation of household waste as well as willingness to recycle[51]

Incentives can work well for someone and at the same time have little effect on others. This is because people's situations vary. Wealthy people who feel they can afford to make trash are completely unconstrained by the system. This is fact that can lead to objections because of unfairness.[52]

Even though incentives can be a motivator for people to recycle, research in the US shows that the effectiveness is not significant and that it does not necessarily lead to a higher participation in recycling. Here the study showed that increasing the price of disposal did not

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[48] Cook and Berrenberg, (1981). Approaches to encouraging conservation behaviours. Journal of Social Issues.

[49] Skinner , B.F. (1971) Beyond freedom and dignity. New York: Bantam Books

[50] Åberg, H. (2000). Sustainable waste management in Households- from international policy to to everyday practice. Experiences from to Swedish field studies. Göteborg Studies in Educational Sciences 150. Acta Universitatis Gothoburgensis

[51] Thorgersen, J. Recycling and Morality. Environment and Behaviour, Vol: 28, 4. 536-559

[52] Gardner, G., Stern, P. (2003). Environmental problems and human behaviour.. p 107

increase the rate of recycling. A reason for this could be that the economical benefit for the households studied was not significant to influence on the recycling behaviour. A price placed on disposal of waste does not necessarily lead to increased recycling since it is an indirect signal to recycle and a direct signal to reduce waste.[53]

Regarding the economical benefit perceived with incentives it is of importance to make the incentive large enough. This is stated as a good design principle for designing pro environmental incentives. It is important though not make an incentive so large that it undermines people's intrinsic motives to act. People can come to believe that they are acting only for the incentive, leading to demanding large incentives that they might previously have done with only small ones. An over justification of behaviour may reduce the long-term effectiveness of incentives that work well in the short term.[54]

4.3 Feedback

One approach to make information more effective is to link it directly to people's behaviour. In the 1970s, psychologists began experimenting with a behaviour that, instead of telling people what to do to save energy, offered higher quality information about how much they were already using. The experiment provided regular, usually daily information about how much energy a household were using, and on what that rate of energy use would cost by the end of the month.[55]

Feedback can be used as a way to inform people whether they are succeeding in their behaviour, whether their behaviour are having an effect or not.[56] Feedback provides more specific and valid information than a general brochure on how to recycle because it is directly related to the household's actual behaviour.

The theory of feedback is an application of operant learning theory from psychology (Skinner 1938, The behaviour of organisms). If people are motivated to save energy, or to lower their energy bills, they will repeat whatever behaviour produce that reward. Although frequent feedback works, its effect is of limited magnitude and ability to endure. Feedback also only works if the participants are strongly motivated.[57]

4.4 Convenience in the design and layout of a source separation system

A convenient system is basically a system that allows for a use that that can easily be integrated and used on a routine basis.[58] Convenience also refers to the possibility of doing an activity with little effort or difficulty. Related to convenience are also situational factors.

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[53] Jenkins, R.R. Martinez S.A., Palmer K., Podolsky, M.J. (2000). The determinants of household recycling: A material specific analysis of recycling program features and unit pricing. Resources for the future. Discussion paper 99-41-REV(online) Available: http://www.rff.org/CFDOCS/disc_papers/PDF_files/9941rev.pdf

[54] Deyoung, R. (1993). Changing behaviour and making it stick. Environment and behaviour, 25, 485-505

[55] Gardner, G., Stern, P. (2003), Environmental problems and human behaviour. p 83

[56] Bell, P.A., Greene T.C., Fischer J.D. & Baum A. (1996). Environmental Psychology. Fourth edition. USA: heartcourt Brace College Publisher

[57] Gardner, G., Stern, P. (2003), Environmental problems and human behaviour. p 83

[58] Berg, Per EO. (1993), Källsortering, teori, Metod och Implementering. Chalmers tekniska högskola

This could be distance to waste disposal and recycling centre. Situational factors also refers types of dwellings were participants live and the space available at home for carrying out the source separation of waste. Situational factors can impose limitations that people have little control on.[59]

In order to obtain as high participation as possible it is important to consider the user's convenience. Even though a user can be motivated and environmentally concerned, inconvenience can produce obstacles or barriers to recycling.[60] Recycling can be more or less far going. The more fractions included, the more work is needed from the user.

In houses and dwellings with multiple apartments collection of waste should be as close to the housing as possible. People are not likely to walk far in order to dispose of waste, whether it is organic waste, paper, glass etc. [61]

4.5 Household population and type of buildings

Type of dwelling is of importance when it comes to source separation. In single apartment households, where a higher commitment and concern for the household living can be expected, the conditions for source separation can be expected to function on a satisfying level regarding participation and quality of the sorted fractions. In areas with multiple apartment housing, were a more anonymous way of living prevails, the personal commitment and motivation can be lower which again influence on the functioning of the source separation system.[62]

Even the social structure in residential areas influence on the outcome of the source separation. Among several variables like size of household, income, age, education and location of housing area, a Dutch study pointed out age as something significant when it comes to behaviour in source separation. The group older than sixty-five in the study, was found to source separate more than the other age groups. A German study made in 2001 also points to age as an important factor. 92 percent of those over thirty separated their waste, while a younger group ageing from sixteen to twenty-nine was less inclined to separate. Women and families were more inclined to waste separate as compared to men and single people respectively. Families' higher interest in waste separation was due to concern in their children's future.[63]

4.6 Obstructions to environmental behaviour

In general there are two main barriers that can keep people from acting on pro environmental attitudes. These are internal and external barriers. The internal barriers can be attitudes and beliefs or absence of appropriate knowledge or commitment. Such barriers exist

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[59] Fenech, M. (2002), Understanding Public Participation in Source Separaion of Waste, IIIEE, Lund University

[60] AFR-Report 24 Swedish Waste research Council. (1993) Motivational factors in waste related behaviour- A Review. Stockholm.

[61] Berg, Per EO. (1993) Källsortering, teori, Metod och Implementering. Chalmers tekniska högskola.

[62] Vafab, Huvudrapport 1996, *Källsortering och biologisk avfallsbehandling i vafab-regionen,* p 20

[63] Fenech, M. (2002) Understanding Public Participation in Source Separaion of Waste, IIIEE, Lund University, p 23

within individuals, and they can be dealt with by aiming information programs at individuals to remove knowledge barriers and increase level of commitment.[64]

The second type of barrier lies outside the individual, and these external barriers could be the individual's socio-economic background, available technology, social and political institutions, economic forces and inconvenience. These barriers can prevent pro environmental attitudes from being expressed. For example attitudes in favour of recycling produce no action when recycling is too inconvenient[65] Inconvenience influence on the individuals motivation to participate. Here inconvenience can be distance to recycling centre, the number of fractions to be sorted, and lack of sorting equipment in the households.[66]

4.7 Economical aspects of extended source separation and introduction of composting facilities in Longyearbyen – Svalbard

Recycling being a practice accepted in modern society, also involves cost, due to more handling, i.e. time cost, and need of additional investment in equipment and facilities. Since this thesis focus on Longyearbyen in Svalbard, it would be interesting to illustrate what the economical aspects are of introducing a more extended waste separation and an introduction of a composting facility.

Based on the most recent waste management plan in Longyearbyen, an overview of the necessary investments are as follows. The waste management plan indicates a step-by-step introduction of source separation and composting.

In the first and initial step the community wants to prohibit disposal of electronic goods and kitchen electronics and instead offer the possibility of receiving these goods for final treatment. Further glass and plastic should be collected from households and local enterprises. Outranged vehicles should also be collected and stored for dismantling, and finally scrap iron should be sent to the mainland for recycling.

Step one would lead to the following investments:

1. Purchasing of waste container for households and local business enterprises
2. Establishment of weighing facilities as a transfer to weight based fees on waste
3. Extending of area used for waste disposal
4. Establishment of reception of scrap iron and outranged vehicles

In the second step an investment in a composting facility is planned for the composting of organic waste, initially to be collected from restaurant kitchens.

In step three an investment will be made in facilities for the collection of organic waste from even the households in Longyearbyen.

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[64] Gardner, G., Stern, P. (2003), Environmental problems and human behaviour. p 78

[65] Ibid. p 79

[66] Werner, C.M. & Makela, E. (1998), Motivations and behaviours that support recycling. Journal of Environmental Psychology 18. 373-386

It is also necessary to during the introduction and on a continuous basis for the recycling in Longyearbyen, to follow up with information campaigns how to use the system and on the different fractions. Information campaigns will also be necessary to influence on the users attitude and knowledge regarding source separation and the environmental benefit of it.

Table 2 The budget for investment and operation of the facilities in Longyearbyen, Svalbard.

The budget for investment and operation of the facilities are as follows. (Figures in NOK 1000)

Investment projects	Investment cost	Annual operational costs	Annual operational income or savings
Step 1			
Waste containers	550	0	0
Weighing facilities	350	35	0
Expansion of disposal area	300	0	0
Reception of vehicles	120	0	0
Step2			
Composting facility	2000	130	10
Step 3			
Extended source-separation households	1000	10	10
Adm. and physical initiatives.	0	255	127
SUM	**4320**	**430**	**147**

4.8 Summary

In the previous chapter we described a systems model describing factors that influence on recycling behaviour. This model dates back to 1993 as mentioned. An interesting question is whether these criteria are valid today? Do they overlap with the criteria described in this chapter that was based on the literature review?

Comparing the criteria in the systems model with the factors from the literature review, we can conclude that the criteria from the model developed in 1993 correlates well. Which factors from chapter four validates the criteria in the systems model is displayed here in the following chart.

Criteria from systems model 1993	Correlating chapter from literature overview
Opinion climate	*4.1, 4.6*
Status of source separation in the selected area	*4.4*
Level of information in connection with introduction and operation	*4.1, 4.3, 4.6*
The use of incentives	*4.2*
Household population and type of building	*4.5*
Practical design of source separation system and distance to waste containers	*4.3, 4.6*

Figure 4 Comparing the criteria in the systems model with the factors from the literature review.

Seeing the correlation we keep the selected criteria from the model from 1993, and we will use them in chapter six where they will be examined for the case of the source separation system in Longyearbyen in Svalbard.

In the following chapter, we will learn more about the Longyearbyen as a settlement and its waste management system.

5. Longyearbyen, Svalbard

5.1 The settlement

The following material is mainly based on the report "Avfall og avfallshantering på Svalbard- Status og forslag til tiltak", Sysselmannens rapportserie Nr.2/1998

Longyearbyen has developed from a community based mainly on mining until the end of the eighties, to a more diversified activity. Longyearbyen lost approx. 100 man/year in the period 1986-96 due to downsizing of the mining activity, but this has been more than compensated, by growth in the tourism sector, research, teaching, merchandise and service. The number of work man/year has increased with approx. 30% from 1989 to 1996 (from 716 to 922). There is also a university at Longyearbyen and if the number of study/year is included the increment is more than 40%. Today there are more than 100 private enterprises and public institutions in Longyearbyen making up for more than 900 man /year.

Especially there has been a growth in the tourism sector. From 1991 to 1996 the number of guests at hotels in Longyearbyen increased threefold. A continued growth is expected in the tourism sector along with space-related activities and research/teaching at UNIS (UNIversity at Svalbard). A prognosis for the period 1996-2001 expects a growth in man/year to 950 (Annual report 1996, Svalbard Näringsutvikling AS (SNU)).

Longyearbyen has several shops, one hospital, several companies in the tourism sector, four hotels, five restaurants/cafeterias, 8 adventure companies, two larger public service buildings (Sysselmanskontoret and Näringsbygget), one universitybuilding (UNIS), as well as an airport and a harbour.

The number of inhabitants in Longyearbyen has increased from approximately 1100 in 1990 to 1300 in 1998, i.e. an increment of nearly 20%. From being a male dominated society, there are now 30% women and 20% children among the inhabitants. Approximately 70% of the housings consist of one person. For 60% of the habitants the duration of the stay is less than three years.

Svalbard Samfunnsdrift A/S (SSD) is responsible for the supply of electricity, water, wastewater, waste management, maintenance of roads and fire protection. Also they are responsible for the two kindergartens and maintenance of all ground in and around Longyearbyen. SSD has 60 employees. All stocks in SSD are since first of January 1993 owned by the Norwegian government.

With very few exceptions, none of the houses or apartments is privately owned in Longyearbyen today. The rentals are mainly different public institutions and private enterprises and the fixed cost for the tenants are covered by their employer. However it is expected that the tenants for the future will have to pay more of the fixed cost themselves, like for example waste management, wastewater fees and so on.

The source of energy in Longyearbyen is supplied by a coal-fired power plant built in 1982.

5.2 Waste management in Longyearbyen

The waste management in Longyearbyen today is based on a waste management plan made in 1990. Some of the results from the implementation of this plan were the opening of a waste management plant in 1991, and the introduction of source separation for all households and enterprises in Longyearbyen in November 1992.

The waste management in Longyearbyen is performed by the company Östbö A/S, and covers both households and enterprises in the town. They are also responsible for the handling of hazardous waste, which is shipped to Bodö in Norway for further treatment (handling).

Information about the routines for waste management in Longyearbyen is given to all the households in the town both in the form of letters to the households and information in the local newspaper "Svalbardposten".

5.3 Current handling waste existing systems for source separation

The system for source separation in the households is based on that each household finds a practical solution for the sorting of generated waste, and then transports it to so called Boch containers. In 1992 there were some attempts made on the introduction of waste bins in the kitchens for household waste. This arrangement was later cancelled due to problems with emptying the rack in the Boch containers.

In all there are 16 Boch containers available for the source separation of aluminium cans, cardboard, paper and glass. In the waste treatment facility 4 containers are available. These are used for replacement of containers that needs to be de-iced during wintertime. The Boch containers are placed within reasonable walking distance for the users.

The sorted fractions are compressed in balls at the waste treatment facility and then transported free of charge with the vessel Polarsyssel to Tromsö. The prices received for the different sorted fractions vary depending on demand and current access to the different fractions at the receiving recycling companies in Tromsö. Aluminium gives a financial surplus unlike the other fractions, which involves a cost.

For waste to be disposed at the landfill in Longyearbyen, containers are placed out in the town, often close to the Boch containers. For this waste to be processed at the landfill, it is compressed into balls before deposition. This includes fractions like plastic, milk cartons and other plastic coated or "polluted" cardboard. Further there are smaller tins, food waste and so on. By compressing the waste into balls there is a reduction of 70-80% reduction in volume. Another advantage is that the problem of free flying waste at the landfill is avoided. The containers are emptied when needed by Östbö A/S.

The fee paid by the households for waste management was in 1997, NOK 975: - for the small apartments and NOK 1950: - for the normal apartments.

The different enterprises in Longyearbyen are responsible themselves for arranging the source separation and the deliverance of the waste to the waste management treatment plant. Special bins for the sorting of paper are supplied by SSD. Sorted paper, glass and aluminium can be delivered free of charge to the waste management treatment plant. However, for other

types of waste different ratings exists for delivering of other waste included hazardous waste. Also rent need to be paid for the waste containers.

At three of the local establishments source separation is practised. The separated fractions are cardboard, paper, glass and aluminium. At the shop "Svalbardbutikken" paper and cardboard are separated and compressed before deliverance to the waste treatment plant. Containers for collection of paper are also located at Näringsbygget and Sysselmannskontoret. Also there exists some collection of glass bottles and aluminium cans in the town.

5.3.1 Reception of waste from boats

Longyearbyen receives waste from boats, mainly food waste. The fee paid by boats is NOK 300: - per m^3. Quite a few cruise ships visit Longyearbyen, and according to sysselmannen in Svalbard the routines for waste management onboard are good.

5.4 Operating the landfill

The current landfill used for disposal of waste from Longyearbyen was established in the autumn of 1991. The landfill receives waste from other settlements in Svalbard as well. These settlements are Ny-Ålesund, Svea and Isfjord Radio. Except from waste that are separated and sent for recycling to the mainland, all waste are disposed at the landfill here in Adventdalen (except from hazardous waste). The waste (food waste, tin cans, plastic and other unsorted waste) is compressed before disposal. By compressing the volume is reduced by 70-80 %. Another effect is that by this procedure flying waste is avoided. Waste (coarse material) that cannot be compressed is disposed directly.

The waste is covered by sand and gravel on a continuous basis. In the wintertime slag from the power plant is used. Samples from the leachate taken on a yearly basis show that the level of metals and diluted nitrogen are low compared to levels on the mainland. Since middle of 1980 no incineration of waste is performed, as decided by the Norwegian Health Council.

5.5 Waste

5.5.1 Waste and waste composition in Longyearbyen

The amount of waste* created from household and enterprises in Longyearbyen has shown a significant increase in the last years. In 1989 the amount was estimated to 970 tons, while in 1996 the estimated amount was 2500 tons. Compared to the mainland in Norway, this equals 2.5 times the amount of waste created there. Considering the growth of population in Longyearbyen this means that the creation of waste has doubled from 0.9 tons per inhabitant in 1989 to 1.9 tons in 1996. The changes are illustrated in the following table.

Table 3 Changes in waste creation

	1989 (approx)	1996 (approx) in tons
Household waste; food, plastic, etc.	410	361
Woodwork and other construction waste	125	1124**
Cardboard	55	67
Paper	145	40
Tin cans aluminium	18	15
Scrap iron	120	130**
Glass	70	433
Hazardous waste	25	30
Total:	**970**	**2550**

*The figures for 1996 are based on monthly reports for volumes of different waste fractions and of processed, as well as examinations of sorted waste in containers

**In total 1604 tons of coarse is registered received, where the division of scrap iron and woodwork is estimated.

5.5.2 Findings landfill

What is significant is that the level of created waste per annum is much higher than estimated at the time for the planning of the landfill. The result is that the landfill is filled up much faster than estimated. The main reason for this seems to be the increased building activity experienced.

When the landfill in Adventdalen was established in 1991 the estimated life length was 75 years. In the summer of 1997 the remaining life length is estimated to be ten years.

5.5.3 Findings source separation in Longyearbyen

Though there is established a source separation system, it is focused on aluminium cans, paper, cardboard and glass. This material is recycled on the mainland. However, a far going source separation, for example including organic waste as a separate fraction, is not yet established. The households have not yet installed any form of standardised equipment for source separation. When it comes to organic waste there is not yet any possibility for separating it from the other household waste. And also, the garbage containers don't leave any room for separated organic waste. Nor are there any routines that focus on organic waste currently. However, this situation can be changed with the introduction of equipment for source separation in the households, and in the enterprises as well as containers that allows for receiving sorted organic waste. The containers today are emptied on demand. Though the climate is cold an examination has to be done on how long the organic waste can be kept in the containers before removed for decomposition. Problems related to this are leachate and then smell.

Another factor is the level of environmental awareness. Though source separation is established in the community and information is dissipated regarding source separation the examination mentioned point to a potential for better participation when it comes to source separation. The reason for this not optimal situation of source separation is not clarified. Some possibilities are of course that people don't stay for a long time, maximum three years, which increase the need for more information. Also 70% of the households are single person household, which as later will be discussed, influence on the quality of the source separation

system. An important question now is to what extent the low participation level around source separation is an indicator of future quality in the source separated organic waste fraction, and how much the disposition of households will influence the quality of the organic fraction. This leaves questions that need to be examined for the future.

An examination conducted by a school class in 1997 shows that there is a considerable potential for reduction of the amount of waste disposed at the landfill. This can be achieved through better participation on source-separation of the waste. By examination of the waste containers on three different locations in the town the conclusions that the landfill received 300 m^3 waste that could be recycled which equals approx. 100 tons. The amount of recycled material shipped to the mainland is equal to 200 m^3 or 70 tons. According to the examination this could be increased to 500m^3 recyclable household waste. As 40% of the recyclable fractions of the household waste are utilised today.[67]

One point here is that currently the organic waste along with tin cans is compressed giving a reduction of volume by 80%. This of course extends the lifetime of the municipally waste dump. On the other hand the effect of the compression is that it takes much longer time for the organic material to decompose.[68]

[67] Avfall og avfallsreduksjon i Longyearbyen. Sluttrapport spörreundersökelse. Svalbard Samfunnsdrift AS Dec. 1998

[68] Miller, G. Tyler. (1996). *Living in the Environment,* Ninth edition. Wadsworth publishing Company.

6. Examination of criteria related to quality of compost

6.1 The Criteria

As was said in chapter three, we are working with a systems model that can serve to predict the possible outcome, the quality aspects of the source separation system. These predictions are based on the given criteria for the model, and could of course be verified with monitoring the waste separation system. The results from the analysis of the criteria will make us able to predict the quality of the compost. Composting has not yet been introduced to Svalbard as a way of handling organic waste, though it is considered in the waste management plan for Longyearbyen. [69]

The following criteria were examined in Longyearbyen for the possible prediction of the quality of the compost.

- Opinion climate
- Status of source separation in the selected area
- Level of information in connection with introduction and drift
- The use of incentives
- Household population and type of building
- Practical design of source separation system and distance to waste containers

6.1.1 Opinion climate: local media

Here the local media was examined, the newspaper Svalbardposten. According to the editor of Svalbardposten, which is issued two times a week, the issue on source separation and composting is hardly ever mentioned. There was an article in Svalbardposten in 1998 on the subject of source separation. According to the editor of the Svalbardposten the issue is hardly present in the newspaper. An interview with the editor, showed a very low presence and actuality. There were only two or three articles concerning the waste management system in one year. In the systems model, three levels of presence are stated. Based on the findings we can conclude the result as shown in the table below.

-	Significant presence and actuality
-	Some presence and actuality
•	Low presence and actuality

Figure 5 Public Opinion Climate

[69] Avfallsplan for Longyearbyen, Svalbard Samfunnsdrift, SSD, Longyearbyen 2000

6.1.2 Status of source separation in the area

In Longyearbyen the source separation has been going on since 1991. The future plans for Longyearbyen and SSD is following the Stortingets strategy in Stortingsmelding no. 8 " Om regjeringens miljövernpolitik og rikets miljötillstand" as well as no. 44 ""Om tiltak for reduserte avfallsmengder, økt gjennivinning og forsvarlig avfallsbehandling". SSD aims for the future is waste reduction, material recycling and energy recovery of waste.

At the present the household themselves organise the facilities needed for sorting their waste, and then transports it to the available containers. There was a test performed in 1992 on the outplacement of sorting facilities, but this was ended due to problems with emptying the equipment in the containers.

The containers, which numbers up to sixteen are placed in a suitable walking distance from the households. These are used for the sorting of cardboard, paper, glass and aluminium cans. The residual waste, there among organic household waste, tin cans, plastic, greasy paper, is compressed into balls, which gives a volume reduction of 60-70 %, and thereafter deposited at Adventdalen. The only type of available source separation system today is the boch containers. According to the investigation among the households made in 1998, several households reported that they were missing the appropriate facilities for the sorting of the waste.[70] There is no clear intention on how to make available the necessary equipment for sorting the waste in the households. SSD visions a flexible system were the household itself is given the responsibility to organise the sorting facilities. Here the household can choose whether it wants to purchase the necessary equipment itself or that sorting facilities is made available for those who want.

A problem here could be the creation of the possibility of obtaining a non-uniform system were the principles of sorting the waste could differ from household to household, thus opening for the possibilities for errors in the level of sorting and priority of the sorted fractions. Should the motivation in the single household be low this would hardly lead to the purchase of any equipment. The incentive to source separate the waste is perhaps higher when the necessary equipment is already available. An important issue here is also that people normally don't stay longer in Longyearbyen than three years. Thus each time a new tenant comes the problem of how to organise the source separation arises.

There are three levels in the systems model for the status of the source separation system. Based on the findings we can decide that the system of source separation is under development as displayed in the table below. This is also verified by the waste management plan for Longyearbyen.

-	Activity on continuous basis
-	Trial
●	Under Development

Figure 6 Status of source separation in the area

[70] Avfall og avfallsreduksjon i Longyearbyen. Sluttrapport spörreundersökelse. Svalbard Samfunnsdrift AS Dec. 1998, p 19

6.1.3 Level of information in connection with introduction and operation

During introduction and operation of a source separation system, there are several channels for disseminating information to the households involved. This could be done through local newspapers, general meetings, brochures, directed information to selected groups, feedback, mass information and campaigns.

At the introduction of the source separation system in Longyearbyen a brochure describing and defining the different fractions was issued to the households. In 1998 there was also an article in the local newspaper "Svalbardsposten" on the issue of source separation. The main effort though was through the brochure.

(•)	Local Newspaper
	General Meeting
•	Brochure
	Directed information to selected groups
	Feedback
	Mass information
	Campaigns

Figure 7 Level of information in connection with introduction and operation.

An interesting point here is that according to an enquiry made in 1998 the households were missing information on how to sort and facilities for sorting the waste and also that sorting of waste was viewed as extra work.

6.1.4 Use of incentives

Today there are no incentives in the form of supplied equipment to the households as well as differentiated taxes for amounts of waste. The tax of waste is based on the size of the households in square metres and not the number of people living there. There is also no reduction of tax in case the amount of waste should be lowered. The fee for renovation was for 1997, NOK 970 for the smaller apartments, and NOK 1950 for the normal apartments.

-	By means of lowered tax
-	By means of sorting equipment

Figure 8 Uses of incentives

6.1.5 Household population

The population of Longyearbyen is approx. 1300. 30% of inhabitants are women and 20% are children. 70% of the households are single households. The duration of stay in Longyearbyen is for 60% of the population three years or less. In 2000, 103 people of the inhabitants were students. The houses are primarily owned by SNSK, SSD and Statsbygg.

The rentals are mostly public and private institutions, and an insignificant number of houses (11 villas) are privately owned.

Characteristic for the population in Longyearbyen is the high level of single households, i.e. only one person per household. Thus we can say that Longyearbyen is dominated by less established households. There are no elderly people living in Longyearbyen, and no households consisting of youth. The living is connected to employment, thus there are no unemployed people living in the town. In case of unemployment people would return to the mainland. The number of immigrants is irrelevant since there are no permanent living in Svalbard. The stay is based on contract with an employer, and the average duration of stay is three years or less. This means that there are usually a considerable fraction of habitants having not stayed in the town for so long, i.e. not so well adapted to routines and habits. However there are some foreign speaking personnel in Svalbard, mainly researchers and students. The number is insignificant though.

(Established households: Households with stable condition and habits. Established routines that is a part of the household's identity and correlates the interaction and relationships in the daily life.)

(Less established households: Households with routines changing from day to day and small households, where the interaction between the households does not imply certain routines.)

The situation can be illustrated in the following chart:

-	Less established households
●	Established Households
●	Very small/single households
-	Youth
-	Elderly people
-	Mixed households
●	Families with children
-	Immigrants

Figure 9 Household population

6.1.6 Type of buildings

None of the households are privately owned. 90 % is owned by the Norwegian state. The duration of stay in Longyearbyen is usually not more than three to four years, this explains the situation with rental apartments.

-	Villas
●	Multiple apartment housing
●	Low houses (2-3 floors)
-	Tall Houses (4 floors or more)

Figure 10 Type of buildings

6.1.6.1 Characteristics of buildings

As was stated in the previous chapter, the type of building is mainly multiple apartment housing. Of the apartments 323 are suitable for families and 567 are suitable for single persons. Only 11 villas exist. The housing in Longyearbyen can be considered as low houses, i.e. not exceeding 3 floors.

Historically Longyearbyen was mainly an industrial site consisting almost all apartment was housing accommodation for Store Norske Mining Company and the Norwegian Government. People would have their house and families at the mainland and the living conditions were similar to that on a construction site, were meals would be eaten together in cantinas. Thus the apartments weren't designed with the need for cooking and preparing meals in mind. After 1980 the situation started changing, with more and more time being spent in the apartments, and meals being prepared individually, hence the need for cooking possibilities arose, even though the apartment initially were not prepared for it, resulting in limited space for cooking.

6.1.7 Practical layout and design of the source separation system

Following we describe which fractions occurs, length to place of disposal of the sorted fractions

The existing fractions that are being separated at the source today are paper, cardboard, glass and aluminium. These fractions are initially sorted by the individual households and then carried to one of the sixteen existing boch containers. The residual fraction, tin cans, food waste, plastic greasy paper/cardboard etc. are put in residual waste containers. Each household is responsible to do the necessary arrangement for sorting into the existing fractions.

Four boch containers are kept in reserve at the dumpsite. The reserve containers are also used in case an in-use container needs to be defrosted (during wintertime). Each boch container is placed out so that the walking distance for each household is acceptable.

6.1.7.1 Existing waste fractions

Classes of sorted waste are as shown in the following chart:

	Burnable
	Other
●	Rest
	Dry
	Hazardous
	Compost
	Moist
●	Paper
●	Glass
●	*Aluminium*

Figure 11 Existing waste fractions in Longyearbyen

6.1.7.2 Classification of walking distance for disposal of waste

The residual waste containers are placed out in the Longyearbyen. Usually close to the boch containers. The waste from the residual waste containers is compressed into balls with an approximate volume reduction of 70-80 percent.[71]

The number of containers allows for a short distance to walk in order to dispose of the residual waste fraction.

	0-immediate distance to household
●	1, short walking distance (no overcoat needed), less than 50 metres
	2, considerable walking distance (overcoat needed), 50-500 metres
	3, vehicle distance, vehicle needed, more than 500 metres

Figure 12 Classification of walking distance for disposal of waste

[71] Avfall of avfallshantering på Svalbard-Status og forslag til tiltak. Sysselmannens rapportserie Nr.2/1998, p 35

7. A possible model showing connections between criteria and quality aspects

For composting as a method of handling organic waste one is dependent on a well functioning source separation system. You want a high level of participation as well as the right fractions to go were they should be. These are quality aspect of a source separation system, and can be verified by on site monitoring of the system. However, keeping track of how well the system is functioning can mean a lot of work. It is necessary though to know, since a well functioning system is necessary if you want to use composting as a way of handling organic waste. There are a number of quality criteria, as previously described.

The source separation system in Longyearbyen is under development. Before deciding to go further and introduce composting as a way of handling the organic fraction, it is of course of great interest to find out how well the system is functioning today. This because if the system does not live up to a certain level of quality requirements, we will end up with an impure end product. Further, an examination of the existing system, can help us to find out were we should allocate resources for the improvement of the system. Finally, it would also indicate if it is possible at all to introduce composting given the circumstances in Longyearbyen.

In the project of 1993 by RVF (RVF rapport 1993:2:1 p.84) a model based on experience was developed, showing the relationship between local criteria and quality aspects. In figure xx. The relationship is marked with the symbol " +".

	Opinion	Status	Information	Motivating instructions	Incentives Equipment	Tax	Household Population type	Housing type	Fraction definition	Distance to disposal
Participation level	+	+	+				+	+		
Sorting outcome	+	+	+		+			+		+
Level of wrong-sorted waste				+				+	+	
Environmental Consequence					+			+	+	
User satisfaction			+		+	+	+			+
Understanding necessity of recycling	+		+				+		+	

Figure 13 Showing interrelationships for necessary criteria and quality aspects for Longyearbyen Svalbard

The above figure can be read as follows: For participation level, opinion climate, status of the source separation system, information, type of household population and housing type will be the major influence.

7.1 Prediction of possible outcome regarding quality aspects in figure 12

By combining the strength of each criteria and the presumed connection with the quality aspects we can make an estimate on a possible outcome regarding the quality aspects. To some degree these estimates can be verified against a picking survey.

7.1.1 Level of participation

Referring to figure 12, the level of participation is mainly depending on opinion climate, status of the source separation system, information, type of household population and housing type.

Longyearbyen opinion climate is characterised by a low level of presence in the news media. The status of the source separation system is that it is under development.

(The source separation system has been developed mainly for recyclable material like glass, paper, aluminium and rest. The fraction, organic household waste, is not treated as a separate unit. For this fraction the system is under development, meaning the plan is for the future to treat it as a separate fraction)

The information level can be considered low. The households are dominated by single households (70%) in multiple apartment housing, i.e. social control can be estimated as low.

By this we can assume that the level of participation will be low. This assumption can be verified by the fact that the level of recovered waste is only 23% compared to the Norwegian mainland, which is 40-60%. Further, the recovered waste from enterprises amounts to 6% as compared on the mainland's 30%.[72]

7.1.1.1 Conclusion

Based on these findings we can estimate that Longyearbyen risk having a low level of participation both now and in the future should the necessary criteria not change.

7.1.2 Sorting outcome

Sorting outcome is partly dependent on the level of participation and partly the household's conditions to sort correctly and consequently. In addition to the criteria assumed influencing on the level of participation, we can also say that the equipment available in the kitchen for source separation influences on the sorting outcome. The equipment serves as a motivating reminder and a practical facilitator, helping to sort correctly and consequently. In case that the work needed for the disposal of some fractions is increased, for example due to longer distance for disposal compared to other fractions, the temptation to "cheat" can be there.

[72] Avfallsplan for Longyearbyen. Svalbard Samfunnsdrift. February 2000, p 17

This of course is prevalent in areas were the social control is less, for example in multiple apartment housing and single households. Cheating occurs when one can do it without being observed and the "misdeed" is not referable to a special household. This is often the case in multiple apartment housing.[73]

The containers for disposal of the different fractions in Longyearbyen are readily available within a distance of less than 50 metres. However, there are no standardised sorting facilities available in the kitchen. It is up to the households themselves to arrange for the source separation in the kitchen. Another factor is that the kitchen is relatively small, not leaving much space for sorting equipment.

7.1.2.1 Conclusion

With a low level of social control, no standard sorting equipment in the kitchen and an anticipated and de facto low level of participation, we can assume that the sorting outcome will be low, both now and in the future with the existing criteria.

7.1.3 Level of wrong-sorted waste

The level of wrong-sorted waste is partly dependent on the share of non-participants, since their "mixed" waste becomes a disturbance in the fraction they appear.

The level of wrong-sorted waste is also dependent of the quality of the sorting instruction and to what extent the fraction definition is understandable and logical for the user of the source separation system.

Comparing the prioritised and not prioritised fractions we can expect the prioritised fractions to have a moderate sorting outcome and low degree of wrong sorting. Following, the not prioritised fraction would have a high level of sorting outcome, but also a high level of wrong-sorted waste. After all, this is where you will put everything you are unsure about, and which have no definite belonging to any waste fraction. This also where the users mixed waste will end up.

The sorting instruction used for Longyearbyen is with clear definitions on the sorted fractions regarding the "residual" waste there are also clear definitions. There is a special container for the residual waste. The waste is defined into 5 categories[74].

1. Treatable waste-sorted
2. Treatable waste-unsorted
3. Coarse waste sorted
4. Recyclable waste group 1
5. Recyclable waste group 2

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[73] Svenska Renhållningsverks-Föreningen RVF 1993, *Beskrivning av sex olika system för källsortering av hushållsavfall*, p 87

[74] Information brochure to households in Longyearbyen

7.1.3.1 Conclusion

Based only on the clear definitions of fractions and rest we can expect that the level of wrong sorting should be low. On the other hand the level of participation is low which in turn could lead to a disturbance in the fractions. Also the fact that the housing type at Longyearbyen consisting of multiple apartment housing allows for little social control, support that we can expect high levels of wrong sorting both now and in the future based on the give criteria.

7.1.4 Environmental consequence

The environmental consequence is dependent on the use of incentives, availability of sorting equipment, housing type and the definitions of fractions.

In Longyearbyen today there are as previously mentioned no incentives used, as well as no standardised sorting equipment available in the apartments. Also there are many small/single households in multiple apartments housing, meaning that the social control is low. It is estimated that 80% of environmental hazardous waste is collected, and the goal is to increase it to 90%. (avf. plan 2000. p17).

By this we can conclude that the waste will contain hazardous components. The variation of content of hazardous waste can be considerable, since this in turn is dependent on variations of number of hazardous objects (batteries, oil-spill, etc.)

The fraction hazardous waste is well defined. However, this should be delivered directly to the towns waste site as well as being marked "specialavfall". The question is to what extent the population is willing to do that since this involves considerable more effort than just "dumping it" in a container.

7.1.4.1 Conclusion

Based on the low level of participation, lack of sorting equipment and incitements, and housing type (low social control) and long and cumbersome distance for delivering hazardous waste we can expect that the waste will contain high fractions of harmful consequence for the environment for now and in the future should the criteria not change.

7.1.5 The systems user satisfaction

This is related to information regarding the use of the source separation facilities. Further, the use of incitements, sorting equipment, household population and distance disposal will determine whether its users will be satisfied or not.

7.1.5.1 Conclusion

Based on the current situation we can conclude that under the current the users in Longyearbyen are more likely not to be satisfied.

7.1.6 The systems ability to generate understanding for the necessity of recycling

The understanding of closed loop principle is something that would influence the users towards a more conscious attitude towards the use of resources. The understanding of this in turn will influence on the longevity of the source separation system.

The understanding of the closed loop principle is dependent of the opinion climate, information, household population and definition of fractions.

Opinion climate is low; the information has not been focusing on creating neither an understanding of the closed loop principle nor the necessity of it. The household population is mainly consisting of single person households. Another factor is the relatively considerably shorter duration of stay per inhabitant in Longyearbyen as compared to that of the mainland, Norway. The duration of stay average to three years. This complicates the communication to the households and a monitoring of the households understanding of the closed loop principle. An examination was made in Longyearbyen on the understanding of waste minimisation. This concluded that the understanding of this was low[75]. This could be an indicator of the level of understanding of the closed loop principle. The issued information to the households has been focused on instructions for the use of the source separation system and the definition of fractions. There has been now campaign in Longyearbyen regarding creating awareness around the closed loop principle.

7.1.6.1 Conclusion

Based on the given criteria in the matrix influencing on the understanding of the closed loop, we can expect that the understanding of the closed loop today is low and will remain so in the future based on the strength of the given criteria. The appearance of the household waste issue in the local media is very low; there has been no special effort regarding creating an understanding of the closed loop system. Further, single households are predominant with a limited duration of stay, a factor that decreases the accessibility when disseminating information.

[75] Avfall og avfallsreduksjon i Longyearbyen. Sluttrapport spörreundersökelse. Svalbard Samfunnsdrift AS Dec. 1998

8. Conclusions and Recommendations

8.1 Summary and discussion regarding possible outcome of quality aspects

Previously we have examined the quality related criteria and the possible outcome regarding the quality aspects of the waste. It is important to emphasis that these estimations are not equal to a factual outcome, but should be seen as a foundation for a discussion and a possible identification of problems regarding the source separation system.

To summarize, at this point the hypothetical outcome of the quality aspect are as follows:

Level of participation:	**Towards Low**
Sorting outcome:	Towards Low
Level of wrong sorting:	Towards High
Environmental consequence:	High level of harmful substances
Level of user satisfaction:	Towards Low
Understanding of closed loop principle:	Towards Low

Figure 14 Summary of hypothetical outcome of quality aspects.

The main factors influencing the above are:

- Low social control due to mostly single household population in multiple apartment housing
- Not developed source separation system
- Low level of participation
- No incentives
- Lack of sorting equipment in the kitchen
- No present public opinion in the media regarding environmental issues

The hypothetical outcome is as described in figure 12 influenced by a number of factors. The outcome could also be understood as quality criteria, and for a well functioning source separation the challenge is to improve on these criteria. By improving on each one of them, we are able to improve on the source separation system as such. Following we will analyse how to move towards a more functioning source separation system, by investigating each of the factors influencing the specific quality criteria. Which factor are we able to change and improve on, and which are given?

8.1.1 Level of participation

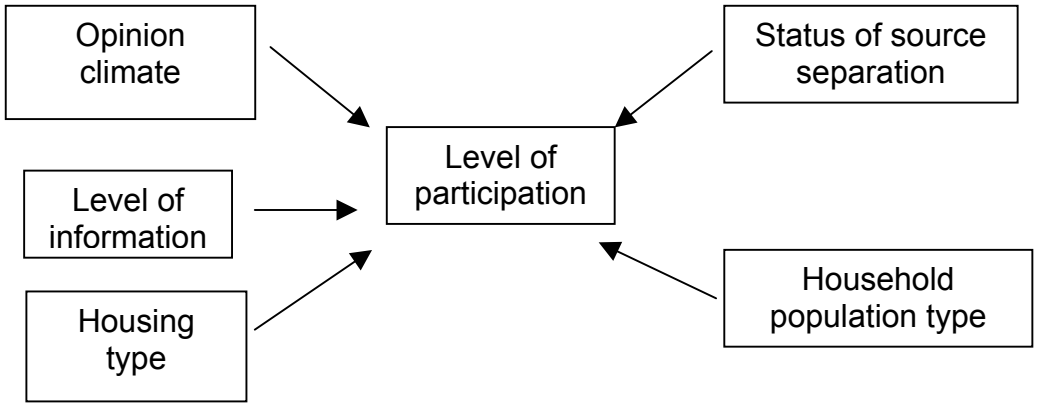

Figure 15 Factors influencing level of participation

As can be seen from figure 14 the factors influencing the level of participation are: opinion climate, level of information, housing type, status of source separation system and household population type. Increasing the level of presence in newsmedia, mass meetings and campaigns can influence opinion climate. Sending more information to the households and ventures in Longyearbyen will increase the level of information. Continuing the development and upgrading of the source separation as planned will lead from a system under development to an established system. The household population type is consists of many single households. However, the tenants are mostly educated people, which are regarded as positive for the commitment, attitude and loyalty towards the source separation system. The housing type consists mainly of multiple housing apartments. This is perhaps the main challenge for the level of participation, because of lack of social control.

8.1.2 Sorting outcome

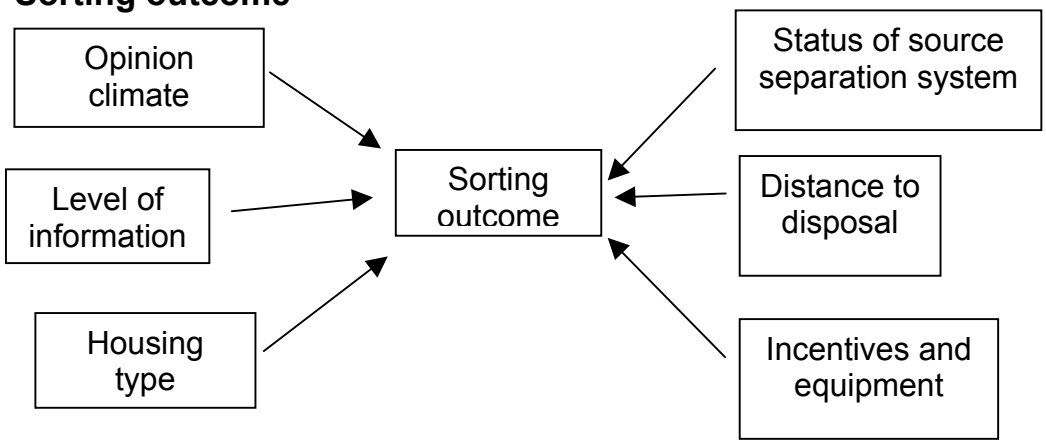

Figure 16 Factors influencing sorting outcome

Sorting outcome, or how share of possible amount goes to the right fraction, is dependent on the factors in figure 15. We recognise the factors opinion climate, status of source separation system, level of information and housing type from figure 14, and these are already commented.

Incentives in the form of equipment for sorting in the households, and distance to disposal are two factors that in addition influence on the quality aspect sorting outcome. There is so far no standardised equipment issued or available to the household. Installing equipment in all households is an incentive for people to participate, since this decreases the time and effort spent in sorting. The second factor, walking distance to disposal, is characterised as short. This means there is no need for improvement regarding this factor.

8.1.3 Degree of wrong sorting

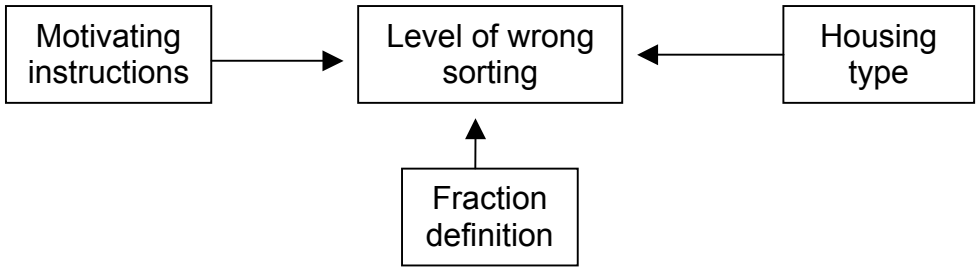

Figure 17 Factors influencing degree of wrong sorting

Wrong sorted material, or how large is the share of wrongly sorted material in a fraction, are determined by the factors motivating instructions, fraction definition and housing type. The two first has mainly to do with information. Longyearbyen has good possibilities to reach the level of motivating instructions through the use of massmeetings, local newspapers with an environmental profile, brochures, directed information through the households and enterprises, feedback system, radio and campaigns. Creating clear fraction definitions is also of great importance in order to improve on the degree of wrong sorting.

8.1.4 Environmental consequence

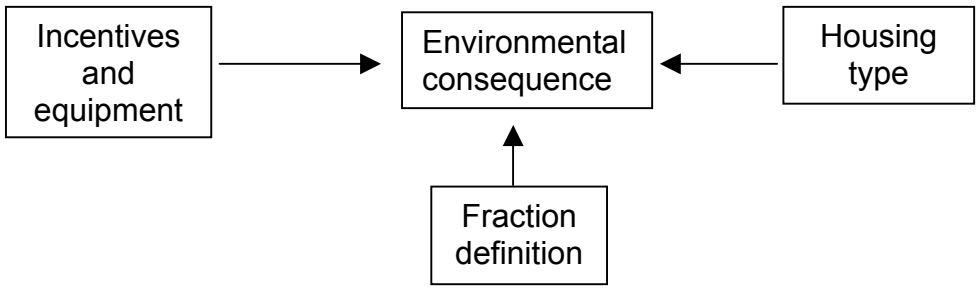

Figure 18 Factors influencing environmental consequence

The environmental consequence, or level of harmful substances in the fractions is dependent on housing type, clear fraction definition and incentives and equipment. As previously

discussed, we are able to influence incentives and equipment as well as giving clear and understandable fraction definitions.

8.1.5 System user satisfaction

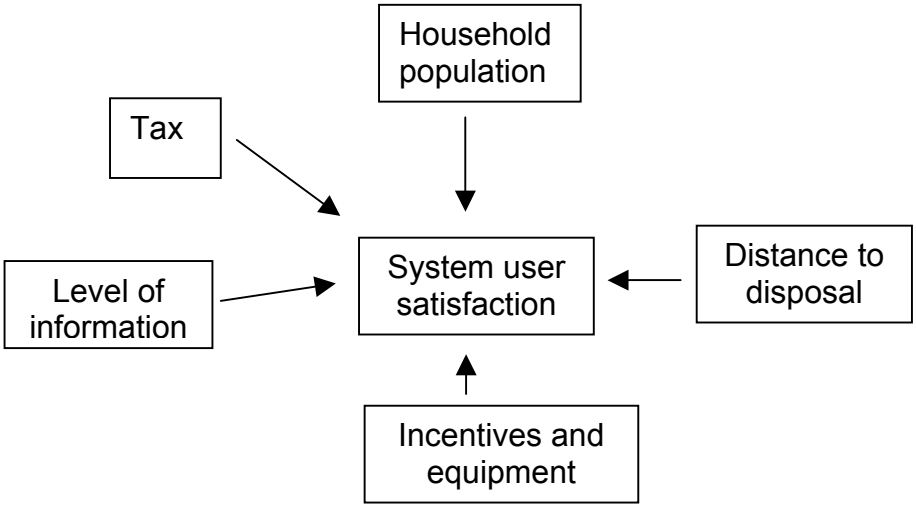

Figure 19 Factors influencing user satisfaction/ dissatisfaction

Whether the users are satisfied or not with the system are of importance for the systems ability to function on a long-term perspective. Except for tax, we have previously discussed the other factors in figure 18. The use of a differentiated tax, for example weight based fee, can be a tool to motivate the users and lead to satisfaction with the system

8.1.6 Understanding of necessity of recycling

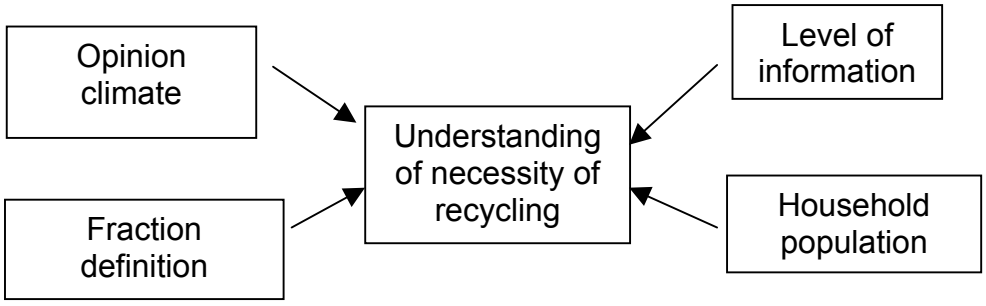

Figure 20 Factors influencing the understanding of the closed loop principle

The understanding of the necessity of recycling could be of importance for the source separation systems ability to survive on the long-term basis. As previously we are able to influence on the factors opinion climate, clear fraction definition and the level of information. The household population type is more or less given.

8.2 Conclusion and recommendations

Having examined and displayed the different factors influencing on the quality aspects of the source separation system, we see that only two out of ten factors are given, and not much can be done to change these on a sort term perspective. The first, housing type, leads to a situation with low social control. The other factor that also must be regarded as constant is that the household in addition to being situated mostly in multiple apartment houses, consists of single households. On the other hand, the single households, which are in majority in Longyearbyen, consist usually of educated people. These are not regarded as critical groups like for example elderly people, youth and immigrants. As for the remaining factors they can all be improved on. This leaves us with actually one given factor of a more challenging character, not being possible to change on a short-term basis.

As discussed for each quality aspects, we are able to improve on the majority of the influencing factors. This in turn makes us able to expect a positive outcome for each quality aspect. With a positive result on each of the quality aspects we will have the indication of a well functioning source separation system, a necessity for the introduction of composting as a way of handling organic household waste.

The recommendations for Longyearbyen to follow in order to achieve a well functioning source separating system is as follows:

- Continue to develop the source separation system, communicating the long term goals to its users

- Continuously informing the public trough motivating information and instructions and attitudinal altering campaigns increasing the level of environmental awareness and understanding of the existing source separation system

- Installing sorting equipment in the kitchen to facilitate the sorting of waste into fractions

- Introducing incitements in the form of fees mirroring the amount of waste delivered from the households

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