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**STUDY ON CRITERIA AFFECTING THE SELECTION OF AERATION
EQUIPMENT**

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<p>This study evaluates the waste water treatment market, concentrating on aeration equipment.</p> <p>The research problems are: What kind of aeration equipment is there in the market? Who are the customers of the aeration equipment manufacturer? What characteristics of aeration equipment are valuable to the customers? Are there differences between the customers?</p> <p>The information has been gathered by means of literature survey and interviews with experts in this field.</p> <p>In this study, aeration equipment is classified into two categories according to the aeration efficiency, that is to aeration equipment with compressed air and equipment without compressed air.</p> <p>The characteristics of aeration equipment are divided into process, product, service, company, and local factors. The importance of the product, service, and company factors to the customers is evaluated. It is concluded that, in this study, no clear differences between the customer groups in relation to the aeration equipment characteristics were found. Local factors are examined in three target countries: Finland, France, and Italy.</p>	
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<p>Tutkimuksessa arvioidaan jätevedenpuhdistusmarkkinoita, keskittyen erityisesti ilmastimiin.</p> <p>Tutkimusongelmat ovat: Minkälaisia ilmastimia on markkinoilla? Keitä ovat ilmastinvalmistajan asiakkaat? Mitkä ilmastimien ominaisuudet ovat asiakkaille arvokkaita? Onko asiakasryhmien välillä eroilla?</p> <p>Ilmastimet jaetaan ilmastustehokkuuden perusteella kahteen ryhmään: laitteisiin jotka käyttävät paineilmaa ja laitteisiin jotka eivät käytä.</p> <p>Tieto on kerätty kirjallisuustutkimuksena ja asiantuntijahaastatteluin.</p> <p>Ilmastimien ominaisuudet jaetaan tässä prosessi-, tuote-, palvelu-, yritys- ja paikallistekijöihin. Tuote-, palvelu- ja yritystekijöiden tärkeys asiakkaille tutkitaan. Tutkimustuloksista voidaan päätellä, että eri asiakasryhmät eivät arvostuksissaan selvästi eroa toisistaan. Paikallistekijät kartoitetaan kolmessa kohdemaassa: Suomessa, Ranskassa ja Italiassa.</p>	
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PREFACE

...that is what learning is. You suddenly understand something you've understood all your life, but in a new way.

- Doris Lessing-

Writing this thesis has cleared my thoughts and I have learned a lot. I am very grateful for this opportunity to work at Nopon Oy, the commissioner of the thesis. I have benefited a lot from its vast knowledge on the aeration of waste water. I would like to thank all the personnel of Nopon Oy for creating an enthusiastic and delightful work environment. I would like to express my gratitude to Tuomo Laukkarinen, product manager at Nopon Oy. His expert guidance helped me all through the study. I have also benefited from fruitful discussions with Mikael Medelberg, marketing manager at Nopon Oy. He gave me many new ideas, and encouraged me to think in new ways. I also want to offer my special thanks to Mikko Ojanen, project engineer at Nopon Oy. He has a good experience, not only of practical work, but also of academic studies. Hannu Kosonen, area manager at Nopon Oy, gave me valuable information on the aeration market in Italy and France. I would also like to express my appreciation to Markku Haikonen for letting me use his research results on contracting companies.

The advice and encouragement of Professor Martti M Kaila at the Institute of Strategy and International Business of the Helsinki University of Technology not only enhanced my research career but also contributed to my professional growth in many ways. I am greatly indebted to him. I would also like to thank Associate Professor Raimo Määttä at the Laboratory of Environmental Protection Technology for his interest in my thesis.

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1 Introduction

1.1 Background to the Study

Nopon Oy produces and markets advanced waste water treatment systems and products for distribution in the world market. It has two product ranges: Nopol[®] fine bubble bottom diffusers and Nopol[®] submerged aerator mixers. Nopon Oy sells aeration equipment to both municipal and industrial waste water treatment plants. The aeration equipment is manufactured in Finland through subcontractors. Exports account for 70 - 85 % of the turnover of the company. Europe and South East Asia are major export markets for Nopon Oy. Exports are made via distributors. The company has distributors in 29 countries.

A rapid development of more stringent effluent standards and new biological treatment processes has been experienced beginning from the 1980s. At the same time, there are significant differences between the actual water protection situation in different countries of the world, for example between the western and the eastern European and northern and southern American countries. There is a trend towards privatisation of the water industry, resulting in turnkey bids, including even the operation and management of the treatment plants. For the research and development function of the company, more information on product features which are valuable to the customers is needed. These developments have led to this study.

1.2 Research Problem

There are two kinds of research problems treated in this study. The purpose of solving these problems is to find new opportunities for Nopon Oy for succeeding in international competition.

The first research problem is the evaluation of the aeration equipment on the market. The core questions here are

- What kind of aeration equipment is there in the market?
- Which is the best way to classify aeration equipment?

The second problem deals with the characteristics of aeration equipment. The core questions are

- Who are the customers for the aeration equipment manufacturer?
- Which characteristics of aeration equipment are valuable to the customers?
- Are there differences between the valuations of aeration equipment characteristics by various customers?

1.3 Objectives of the Study

The first objective of this study is to classify and evaluate the various forms of aeration equipment. There are not many publications on this subject. It is clear that a study which summarises all the techniques used is needed.

The second objective of this study is to find out which characteristics of the aeration equipment and of the aeration equipment manufacturer are valuable to the customer. It is also important to find the main differences between the customers. It is probable that various customer groups value different features of aeration equipment.

This study will also serve as a guide when evaluating new markets for aeration equipment. The third objective of this study is to get acquainted with the aeration market in three target countries.

1.4 Scope of the Study

The study can be divided into three parts. First, the various forms of aeration equipment are evaluated. The aeration equipment is developing all the time.

This study is going to identify the techniques in use nowadays and the arising new aeration techniques, and to define the properties of these techniques. This information can be used when finding selling arguments for the Nopol[®] aeration equipment. It is also important to be aware in advance when there is new, advanced aeration equipment coming onto the market.

In the second part, the customers of the aeration equipment manufacturer are defined. Then the factors affecting the selection of aeration equipment are identified. The major reason for writing this paper is to find out which factors affect the selection of aeration equipment. These factors can be divided into factors related to process, product, service, company, and local situation. The importance of these factors is studied by interviewing the customers.

In the third part, three countries are taken as examples, and the local situation in these countries is studied in more depth. These countries are Finland, France, and Italy. Finland has been chosen since it is the home market of Nopon Oy, and since it represents a mature market for aeration equipment. In France, the waste water treatment is advanced, and the market is widely dominated by few consulting and contracting companies. There is strong domestic competition. Italy represents southern Europe, where the aeration market is still developing.

1.5 Research Approaches and Research Methods

This study uses the decision-making approach. This approach applies problem-solving methods.

The data is gathered by means of literature survey and interviews with experts in this field. Nopon Oy has taken part in the product development project Need Assessment Systems for Technological Applications, coordinated by the Department of Industrial Engineering and Management of Lappeenranta University of Technology. As part of this project, various customers were interviewed. This study uses the results of the product

development project as a basis for quantitative analysis to evaluate the importance of various factors to the customers. The study is based on literature which will be supplemented by interviews with closed-ended questions and inquiries to various countries. The results of the study on the Chinese waste water treatment market by Markku Haikonen will also be used in evaluating the factors affecting the aeration equipment selection.

A lot of information on competing aeration equipment was gathered during the 11. International Trade Fair for Waste Water and Waste Disposal: Sewage, Refuse, Recycling, Public Cleansing and Winter Road Service, in München, Germany in May 1996.

2 Aeration Equipment

There are two basic methods of aerating waste water. These are

- to introduce air or pure oxygen into the waste water
- to agitate the waste water mechanically to promote dissolution of oxygen from the atmosphere¹

Both of these methods are used commonly. Traditionally, aeration equipment has been classified according to the aeration method, that is into mechanical and diffused air aeration equipment. Another common classification has been to divide the aeration equipment into bottom and surface aeration equipment according to the location of the equipment in the basin. However, these classifications have restrictions. Sometimes it is difficult to define the group. For example, there is equipment which uses both mechanical means and air diffusion. The location of the aeration equipment in the basin is not very relevant to the aeration efficiency, either. Some surface aerators have air suction pipes with which they can aerate deep basins as well.

In this study, the aeration equipment will be classified according to the method of air supply, that is into aeration equipment requiring compressed air and into equipment not requiring compressed air. Compressed air devices are much more efficient than the devices not using compressed air, but the investment and operation costs are higher because of the air compression equipment. Compressed air is usually supplied by blowers. More than half of the energy in a waste water treatment plant is expended in the activated sludge stage². Thus, the actual efficiency of the aeration equipment is of paramount importance. The aeration equipment

¹Tchobanoglous, G. 1991. Wastewater Engineering: Treatment, Disposal, and Reuse. Singapore, McGraw-Hill. Page 556.

²Pflüger, W. 1995. Choosing Wastewater Bubble Aerators. Water Management International. Pages 81 - 84.

classification used in this study is shown in Table 1. This classification can be justified by the fact that usually it is specified already in the tender phase of a project whether the aeration should be accomplished with or without compressed air. Nopon Oy's both aeration equipment systems require compressed air.

Table 1. Aeration equipment

AERATION WITH COMPRESSED AIR	AERATION WITHOUT COMPRESSED AIR
DIFFUSERS DISC PLATE TUBE DOME POROUS ROTATING DISC FIXED ORIFICE DIFFUSERS VALVED ORIFICE DIFFUSERS STATIC TUBE AERATORS PERFORATED HOSES JET AERATORS TURBINE AERATORS WITH COMPRESSED AIR PURE OXYGEN SYSTEMS	ASPIRATING AERATORS SURFACE AERATORS LOW SPEED MEDIUM SPEED HIGH SPEED BRUSH AERATORS

2.1 Aeration Equipment Using Compressed Air

Aeration equipment using compressed air includes various diffusers, static tube aerators, perforated hoses, jet aerators, turbine aerators, porous rotating discs, and pure oxygen systems.

Blowers are quite expensive. Oxygen generation is even more expensive. However, the aeration efficiency is much better with compressed air than without. The use of pure oxygen increases the efficiency even further.

Diffusers

In most diffused air systems, air is introduced near the bottom of the basin through porous or non-porous diffusers. Oxygen transfer and mixing occur as air bubbles rise to the surface³. Usually, the diffused air system consists of diffusers submerged in the waste water, header pipes, air mains, and the blowers and accessories through which the air passes⁴.

Dome, disc, and tube diffusers are mounted on or screwed into air manifolds, which may run the length of the basin close to the bottom and along one side; or short manifold headers may be mounted on movable drop pipes on one side of the basin. With the movable drop pipes, it is possible to raise a header out of the water without interrupting the process and without dewatering the basin. The diffusers can then be removed for cleaning or replacement⁵.

In diffused air systems, the control of dissolved oxygen concentration is most often achieved by tapering the numbers of diffusers down the aeration line. Dissolved oxygen electrodes are used to control the operation of separate blowers linked to different zones in the basin, or to alter blower speed⁶. Diffusers are generally considered to offer the best performance with regard to the control of aeration efficiency⁷.

The oldest and most common type of porous material on the market is ceramic. It consists of rounded or irregularly shaped mineral particles

³Qasim, S R. 1985. Wastewater Treatment Plants. Planning, Design, and Operation. New York, CBS College Publishing. Page 315.

⁴Tchobanoglous, G. 1991. Wastewater Engineering: Treatment, Disposal, and Reuse. Singapore, McGraw-Hill. Page 556.

⁵Tchobanoglous, G. 1991. Wastewater Engineering: Treatment, Disposal, and Reuse. Singapore, McGraw-Hill. Pages 556 - 560.

⁶Ainsworth, G & Gill, T. 1987. The Activated-Sludge Process: What Would' Fowler, Ardern and Lockett Say Now? Water Pollution Control, volume 86. Pages 220 - 234.

⁷Ojanen, M. 1994. Biologisen ravinteidenpoiston tekniikka. Helsinki University of Technology, Laboratory of Sanitary and Environmental Engineering, Master's Thesis. Page 58.

bonded together to produce a network of interconnecting passageways through which compressed air flows. Today, the majority of ceramic diffusers being marketed are manufactured from aluminium oxide. Other types of ceramic media composition include vitreous-silicate-bonded grains of pure silica and resin-bonded grains of pure silica^{8,9}.

Ceramic diffusers are very often installed in the nitrification zone. This is because of the longer-lasting high oxygen transfer efficiency compared with membrane diffusers. Ceramic diffusers are very solid and strong. However, because of the method of manufacture they have a very rough inner surface where sludge particles are held back, causing pressure increases. Cleaning can be carried out by heating up the diffusers and incinerating the organic matter¹⁰. Naturally, the process must be stopped for cleaning. Cleaning during operation can be achieved with injected HCl gas¹¹.

The next step was the use of porous plastic materials. The advantages of the plastic material over ceramic are said to be its lighter weight, which makes it highly suitable for lift-out applications, lower cost, and better durability. Depending on the actual material, plastic has also greater resistance to breakage. Disadvantages include reduced strength and susceptibility to creep. Porous plastics are made of thermoplastic polymers. The two most common types of plastic materials in use are high-density polyethylene and styrene-acrylonitrile¹². When porous plastic diffusers become clogged, they have to be replaced. The price of porous plastic diffusers is lower than that of ceramic diffusers, so that replacement may not cost much more than

⁸Anon. 1988. Aeration. Manual of Practice FD - 13. Water Pollution Control Federation. Page 22.

⁹Pöpel, H J & Wagner, M. Grundlegende Einflußfaktoren zur Optimierung von Druckluftbelüftungssystemen. Institut für Wasserversorgung, Abwasserbeseitigung und Raumplanung der Technischen Hochschule Darmstadt.

¹⁰Pflüger, W. 1995. Choosing Wastewater Bubble Aerators. Water Management International. Pages 81 - 84.

¹¹Sanitaire product brochure.

¹²Anon. 1988. Aeration. Manual of Practice FD - 13. Water Pollution Control Federation. Pages 22 - 23.

cleaning¹³. Some of the porous plastic diffusers can be cleaned during operation through the injection of formic acid.

In the 1980s, a new diffuser material was introduced. The membrane diffuser consists of a thin flexible sheath made from soft plastic or synthetic rubber. Air passages are created by punching minute slots or holes in the sheath material. When the air is turned on, the sheath expands and each slot acts as a variable aperture. When the air is turned off, the slots close. This enables intermittent use, as needed in biological nitrogen removal¹⁴. Ethylene-propylene-diene monomer and silicone are the most common membrane materials.

Disc Diffuser

Disc diffusers are probably the most common kind of aeration equipment with compressed air. Disc diffusers are available in diameters that range from approximately 18 to 50 cm. Nopon Oy produces sintered plastic and membrane disc diffusers. It has a system where both the discs fit the same structure. This gives greater flexibility while the sintered discs can be changed to membrane discs if the process is revamped for nitrogen removal, for example. The system is illustrated in Figure 1.

Other manufacturers of disc diffusers are Sanitaire, Suprafilt, Didier, Envirex, Roediger, Huber + Suhner AG, Ingenieurbüro Karl-Heinz Schüssler für Umwelttechnik, and Gesellschaft für Verfahren der Abwassertechnik mbH. Ingenieurbüro Karl-Heinz Schüssler für Umwelttechnik has launched a new model onto the market. The diffuser has a hole in the centre. This is said to increase aeration efficiency. There is also a trend for developing larger diffusers. Several manufacturers have oval diffusers which are something between disc and panel diffusers.

¹³Pflüger, W. 1995. Choosing Wastewater Bubble Aerators. Water Management International. Pages 81 - 84.



Figure 1. Disc diffuser¹⁵

Plate Diffuser

Up until the late 1970s, ceramic plates were rivalled in popularity only by tube systems as the most prevalent form of porous media diffuser¹⁶. Plate, also called panel, diffusers are traditionally square ceramic plates installed in concrete or aluminium plate holders, which may be set either in recesses or on the bottom of the aeration basin. A plate diffuser is shown in Figure 2.

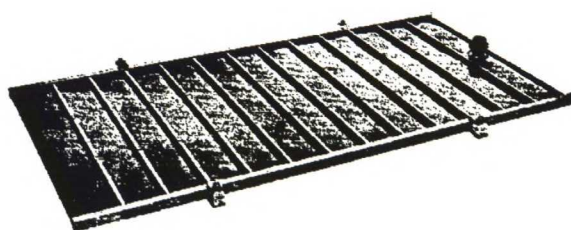


Figure 2. Plate diffuser¹⁷

¹⁴Pflüger, W. 1995. Choosing Wastewater Bubble Aerators. Water Management International. Pages 81 - 84.

¹⁵Nopol® Product Manual.

¹⁶Anon. 1988. Aeration. Manual of Practice FD - 13. Water Pollution Control Federation. Page 23.

¹⁷Messner product brochure.

Although still available, plate porous diffusers have declined in popularity since the advent of the dome and disc diffusers. One explanation for this is the difficulty of obtaining uniform air distribution with numerous plates attached to the same plenum. It is also inconvenient to remove plates when they are grouted in place, and it is not very easy to add diffusers to meet future increases in plant loading either. In addition, they are costly to install and difficult to maintain^{18,19}. However, it seems that plate diffusers are gaining in popularity again. Several companies, including Messner Technik, Suprafilt, Oxyflex, and Gesellschaft für Verfahren der Abwassertechnik mbH, have developed membrane plate diffusers.

Tube Diffuser

Most tube diffusers on the market are of the same general shape. Because of the inherent shape, it is sometimes difficult to ensure air discharge along the entire circumference of the tube. In general, less air flow can be expected out of the bottom of the diffuser because the air must be discharged against higher water pressure. The dead areas can provide sites for slime growth and other foulant development²⁰.

A liftable tube diffuser installation is shown in Figure 3. Tube diffusers can also be fixed to the bottom of the aeration basin in the same way as disc diffusers. The main applications for tube diffusers are small treatment plants, liftable systems, sludge aeration, and fish farming²¹. Tube diffusers are especially popular in Germany. In most countries tube diffusers are regarded as obsolete but in Germany the development work has continued. Most of the tube diffuser manufacturers are little German companies. OTT System,

¹⁸Anon. 1988. Aeration. Manual of Practice FD - 13. Water Pollution Control Federation. Page 23.

¹⁹Tchobanoglous, G. 1991. Wastewater Engineering: Treatment, Disposal, and Reuse. Singapore, McGraw-Hill. Pages 556 - 560.

²⁰Anon. 1988. Aeration. Manual of Practice FD - 13. Water Pollution Control Federation. Pages 26 - 27.

²¹Nopol® Product Manual.

Invent, Envirex, Schumacher, Ingenieurbüro Karl-Heinz Schüssler für Umwelttechnik, Gesellschaft für Verfahren der Abwassertechnik mbH, Didier, Sanitaire, and Aeroflex market tube diffusers. The German van Nordenskjöld has a Biolak system which also uses tube diffusers.

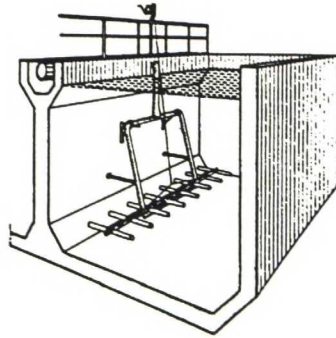


Figure 3. Liftable tube diffuser installation²²

Dome Diffuser

The ceramic dome diffuser was first developed in 1954 by the British company Hawker Siddeley Water Engineering Ltd, and it was refined to its present form by 1961. It has become an accepted standard in England and used to be popular in the United States²³. The dome diffuser is essentially a circular disc with a downward-turned edge, see Figure 4. Dome diffusers are not very popular in continental Europe. There was only one company, Schumacher, at the 11. International Trade Fair for Waste Water and Waste Disposal in München in May 1996 selling these.

²²Peltokangas, J. 1994. Vesi- ja ympäristönsuojelutekniikan perusteet. Tampere, Tampere University of Technology. Page 159.

²³Anon. 1988. Aeration. Manual of Practice FD - 13. Water Pollution Control Federation. Page 24.

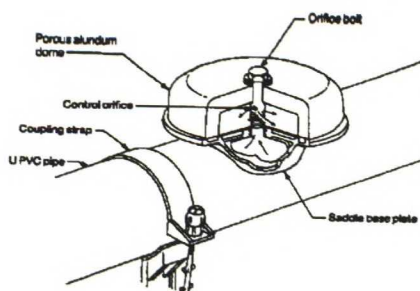


Figure 4. Dome diffuser²⁴

Porous Rotating Discs

Porous rotating discs are combined diffused-air mechanical aerators. The air diffusion is improved by mechanical movement. Porous rotating discs have a cored impeller with a porous top plate secured to a hollow shaft, shown in Figure 5.

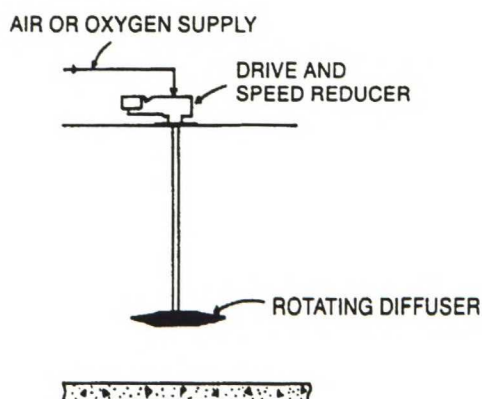


Figure 5. Submerged porous aerator with forced air²⁵

In the porous rotating discs, fixing blades are attached to the impeller. During operation, air or oxygen is blown through the hollow shaft in the impeller core and it passes through the porous plate. The bubbles are sheared off the porous plate top by the friction forces between the liquid and rotating disc. The shearing effect ensures micron-sized bubble formation. The bladed impeller produces vertical circulation and general rotation of the bulk liquid.

²⁴Gray, N F. 1990. Activated Sludge, Theory and Practice. New York, Oxford University Press. Page 68.

²⁵Anon. 1988. Aeration. Manual of Practice FD - 13. Water Pollution Control Federation. Page 86.

This is also influenced by vessel geometry. As with other porous plate units, filtering of the air or oxygen is important²⁶. Porous rotating discs are not very common. Zimpro Inc. of United States produces this kind of aerators²⁷.

The German company Invent has developed an aeration system which uses the same principle: air bubbles are mixed into water through mechanical movement. Their HypoAir stirring and aeration system, shown in Figure 6, has a ring-shaped tube with slots which form air bubbles. The hyperboloid mixer mixes the bubbles into the water. The mixer can also be used without an air flow. The movement prevents clogging of the slots. The mixer is available with submersible drive, or the drive can be located above the water surface.

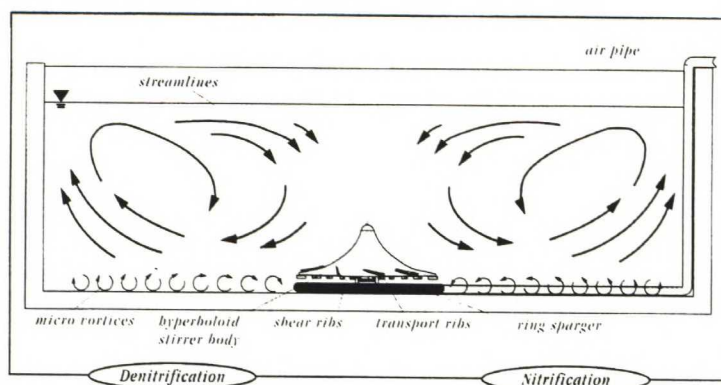


Figure 6. HypoAir stirring and aeration system²⁸

Fixed Orifice Diffusers

Fixed orifice diffusers vary from simple holes drilled in piping to specially configured openings in metal or plastic fabrications. Included in this category are perforated piping, spargers and slotted tubing.

²⁶Anon. 1988. Aeration. Manual of Practice FD - 13. Water Pollution Control Federation. Pages 85 - 86.

²⁷Kiiskinen, S. 1986. Ilmastuslaitteet. In: Kiiskinen, S, Lindqvist, H, Noukka, K, Rantala, P, Tantt, U & Viikari, P. Jäteveden puhdistuksen uudet menetelmät ja laitteet. Helsinki, INSKO 184 - 86. Pages XIII 1 - 20.

²⁸Invent product brochure.

Perforated piping is the basic nonporous, fixed orifice diffuser type. Diffused air has been used in biological waste water treatment from the 1910s onwards. Perforated piping is one of the earliest aeration equipment²⁹. These units deliver air through drilled holes spaced at intervals along the piping. A perforated pipe is shown in Figure 7. Despite their low transfer efficiency, perforated pipes are still occasionally used for temporary expediency or for unusual clogging conditions, in which quick cleaning characteristics are more important than air economy³⁰.

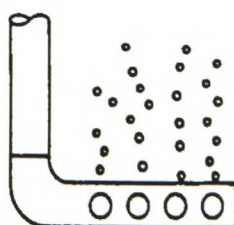


Figure 7. Perforated pipe³¹

Spargers are another fixed orifice diffuser type. They were introduced in 1954 to provide nonclog performance with transfer efficiencies greater than perforated pipes. Spargers are typically constructed of moulded plastic and are saddle mounted below the air header. Figure 8 shows a sparger. Another type of sparger is mounted on individual drop piping³².

²⁹Anon. 1988. Aeration. Manual of Practice FD - 13. Water Pollution Control Federation. Page 21.

³⁰Anon. 1988. Aeration. Manual of Practice FD - 13. Water Pollution Control Federation. Page 27.

³¹Benefield, L D & Randall, C W. 1980. Biological Process Design for Wastewater Treatment. New Jersey, Prentice Hall. Page 296.

³²Water Pollution Control Federation. 1988. Aeration. Manual of Practice FD - 13. Pages 27 - 28.

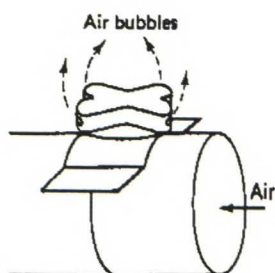


Figure 8. Sparger³³

Valved Orifice Diffuser

Valved orifice diffusers incorporate a check valve to prevent backflow when the air is shut off. Several of these devices also allow adjustment of the air flow by changing either the number or the size of the orifices through which air is released. Valved orifice diffusers are generally mounted on the crown of distribution headers as opposed to the invert of the header as in many fixed orifice devices³⁴. Numerous types of valved orifice devices are available, one of which is shown in Figure 9.

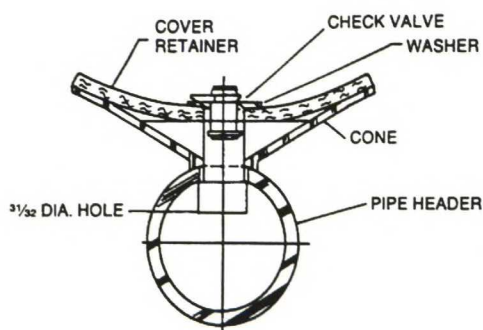


Figure 9. Valved orifice diffuser³⁵

The fixed and valved orifice diffusers produce larger bubbles than porous diffusers and consequently have a somewhat lower aeration efficiency. The advantages of lower cost, less maintenance, and the absence of stringent air

³³Benefield, L D & Randall, C W. 1980. Biological Process Design for Wastewater Treatment. New Jersey, Prentice Hall. Page 296.

³⁴Anon. 1988. Aeration. Manual of Practice FD - 13. Water Pollution Control Federation. Pages 28 - 29.

³⁵Anon. 1988. Aeration. Manual of Practice FD - 13. Water Pollution Control Federation. Page 29.

purity requirements can offset the slightly lower efficiency in some applications³⁶. Fixed and valved orifice diffusers are more commonly employed than porous diffusers in waste water applications where mixing is more important than oxygen transfer. These include aerated grit basins, channel aeration, sludge and septage storage, and flocculation chambers³⁷. Porous diffusers are more common in the activated sludge process.

Static Tube Aerator

The static tube aerator is similar to an air-lift pump with interference devices within the tube, see Figure 10. In the static tube aerator, air is introduced at the bottom of a circular tube. Internally, the tube is fitted with alternately placed deflection plates to increase the contact of the air with the waste water. Aeration efficiency is satisfactory but mixing capability is not very good³⁸. Degrémont's Dipair is an example of a static tube aerator. It is especially suited for deeper basins³⁹. However, Degrémont has stopped producing static tube aerators. Kenics Corp. produces static aerators in the United States. Their Static Mixer is mostly used in aerated lagoons⁴⁰. Static tube aerators are not very common nowadays.

³⁶Tchobanoglous, G. 1991. Wastewater Engineering: Treatment, Disposal, and Reuse. Singapore, McGraw-Hill. Page 561.

³⁷Anon. 1988. Aeration. Manual of Practice FD - 13. Water Pollution Control Federation. Page 30.

³⁸Kiiskinen, S. 1986. Ilmastuslaitteet. In: Kiiskinen, S, Lindqvist, H, Noukka, K, Rantala, P, Tantt, U & Viikari, P. Jäteveden puhdistuksen uudet menetelmät ja laitteet. Helsinki, INSKO 184 - 86. Pages XIII 1 - 20.

³⁹Stenberg, F. 1989. Dipair, staattinen ilmastin syviä altaita varten. In: Väänänen, P, Lehtokari, M, Virtanen, J, Kiuru, H & Pihlajamaa, J, editors. Jäteveden puhdistamoiden viimeisimpiä prosessi- ja laiteratkaisuja. Helsinki, INSKO. Pages V 1 - 5.

⁴⁰Kiiskinen, S. 1986. Ilmastuslaitteet. In: Kiiskinen, S, Lindqvist, H, Noukka, K, Rantala, P, Tantt, U & Viikari, P. Jäteveden puhdistuksen uudet menetelmät ja laitteet. Helsinki, INSKO 184 - 86. Pages XIII 1 - 20.

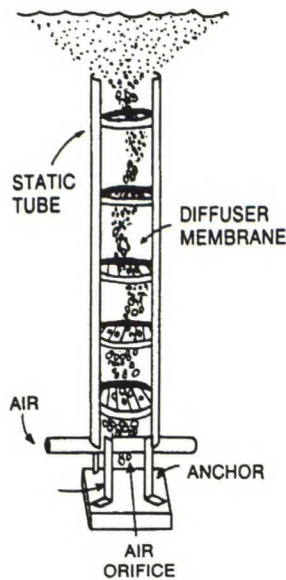


Figure 10. Static tube aerator⁴¹

Perforated Hose

The perforated hose consists of polyethylene tubing which is held on the floor of the basin. Slits or holes along the top of the hose release air. The size and spacing of apertures can be varied. The tubes are fed from air manifolds running lengthwise along the side of the basin. The tubing is installed across the width of the basin⁴². A perforated hose is a common method of aeration in shallow aerated lagoons and oxidation ditches⁴³.

Jet Aerator

Jet aeration is a diffused air system⁴⁴. A jet aerator is shown in Figure 11. It combines liquid pumping with air diffusion. The pumping system recirculates liquid in the aeration basin, ejecting it with compressed air

⁴¹Anon. 1988. Aeration. Manual of Practice FD - 13. Water Pollution Control Federation. Page 30.

⁴²Anon. 1988. Aeration. Manual of Practice FD - 13. Water Pollution Control Federation. Page 29.

⁴³Anon. 1988. Aeration. Manual of Practice FD - 13. Water Pollution Control Federation. Page 30.

⁴⁴Qasim, S R. 1985. Wastewater Treatment Plants. Planning, Design, and Operation. New York, CBS College Publishing. Page 309.

through a nozzle assembly. A typical nozzle has a 2.5 cm opening through which the air and mixed liquor can pass. This system is particularly suited to deep basins⁴⁵. Jet aerators are configured either as cluster aerators or as directional aerators⁴⁶. Jet aerators are commonly used in sequencing batch reactors. Pentech Div. and Mass Transfer Systems, Inc. are the best known jet aerator manufacturers. Jet aerators seem to be more popular in the United States than in Europe.

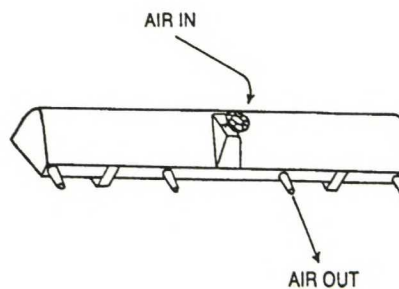


Figure 11. Jet aerator⁴⁷

Turbine aerators with compressed air

Turbine aerators with forced air are also called combined diffused-air mechanical aerators. Turbine aerators with compressed air are normally used at medium-sized and larger plants. They have good mixing capability and can be installed in deep basins with a liquid depth of 6 m or deeper. The controllable flow of air affords a relatively wide range of aeration efficiency control. The aerators are convenient for winter operation and are used, in fact, in several cities and at pulp and paper plants in the northern countries⁴⁸.

⁴⁵Tchobanoglous, G. 1991. Wastewater Engineering: Treatment, Disposal, and Reuse. Singapore, McGraw-Hill. Page 561.

⁴⁶Anon. 1988. Aeration. Manual of Practice FD - 13. Water Pollution Control Federation. Pages 30 - 31.

⁴⁷Anon. 1988. Aeration. Manual of Practice FD - 13. Water Pollution Control Federation. Page 31.

⁴⁸Anon. 1988. Aeration. Manual of Practice FD - 13. Water Pollution Control Federation. Page 95.

A submerged turbine aerator is shown in Figure 12. This is the Nopol[®] submerged aerator mixer produced by Nopon Oy. The air is introduced to a rotor which rotates near the basin bottom. There air is mixed in small bubbles with the water and sludge mixture. Air is supplied by a compressor. The rotating rotor distributes the air uniformly to the whole basin and, at the same time, takes care of the mixing. It is also possible to mix without air supply, which makes the aerator suitable for biological nutrient removal processes. Another advantage is that it is possible to lift the aerator from the basin for reparation and maintenance without interrupting the process⁴⁹. Most of the installations are in industrial waste waters but the aeration of municipal sewage can also be achieved in this way.

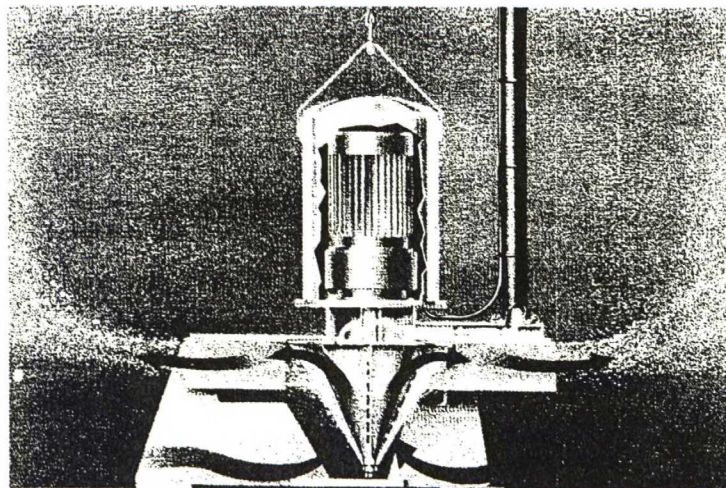


Figure 12. Submerged aerator mixer⁵⁰

In biological nutrient removal processes, it is often required that one zone is alternately aerated and not aerated. In this case both aerators and mixers are needed. When the zone is aerated, aeration inhibits the suspension of the sludge. When the zone is not aerated, mechanical mixers keep the sludge in

⁴⁹Ojanen, M. 1994. Biologisen ravinteidenpoiston tekniikka. Helsinki University of Technology, Laboratory of Sanitary and Environmental Engineering, Master's Thesis. Page 73.

⁵⁰Nopol[®] product brochure.

suspension. Another solution is the use of submerged aerator mixers which permit mixing without aeration⁵¹.

In the future, it will be important for the maintenance and reparation of the aeration equipment to be carried out without stopping the process, and without emptying the aeration basin. This is because of the strict emission limits, the sensitivity of the aerobic waste water treatment process, and slow start-up. It is expected that liftable systems will become more common.

Other manufacturers of turbine aerators with compressed air are the German Frings and the Japanese Hanshin.

Pure oxygen systems

The concept of using high-purity oxygen in the activated sludge process was first considered in 1934. The subject was revived after World War II with the advent of relatively low-cost, simple oxygen generation plants. Since that time, the technology has progressed to a point where the high-purity oxygen activated sludge treatment system is recognised as a significant advance in the waste water treatment field⁵².

The on-site production of oxygen can be provided either by the distillation of air at cryogenic temperatures or through adsorption units⁵³. The development of the pressure swing adsorption system for producing pure oxygen in small quantities at an economical cost has generated renewed interest in the pure oxygen activated sludge process. The paper industry is

⁵¹Ojanen, M. 1994. Biologisen ravinteidenpoiston tekniikka. Helsinki University of Technology, Laboratory of Sanitary and Environmental Engineering, Master's Thesis. Page 60.

⁵²Anon. 1988. Aeration. Manual of Practice FD - 13. Water Pollution Control Federation. Pages 153 - 154.

⁵³Anon. 1988. Aeration. Manual of Practice FD - 13. Water Pollution Control Federation. Page 156.

the largest industrial user of the process. However, a comparison study⁵⁴ of paper industry installations did not demonstrate a definite superiority to the conventional activated sludge process.

Atmospheric air only contains 21 % oxygen, so using pure oxygen instead of air will increase the saturation concentration of oxygen by a factor of five, thereby significantly increasing the oxygen transfer rate. Pure oxygen systems are claimed to have the following advantages over air systems:

- improved rates of biological oxygen demand removal
- reduced sludge yields
- improved settling characteristics of the sludge
- less susceptibility to shock loading
- reduced aeration basin volume
- improved sludge dewaterability^{55,56}.

The cost of producing oxygen is one of the limiting factors⁵⁷. The complexity of the process requires more from operation and maintenance. The use of oxygen also increases the risk of fire or explosion⁵⁸.

Submerged turbines, mechanical aerators, and submerged rotating diffusers are typical aeration methods in the pure oxygen systems⁵⁹. There are two main types of pure oxygen activated sludge systems, those that operate in

⁵⁴Springer, A M. 1986. Industrial Environmental Control, Pulp and Paper Industry. New York, John Wiley & Sons. Page 240.

⁵⁵Sidwick, J M, Lewandowski, T P & Allum, K H. 1975. An Economic Study of the Unox and Conventional Aeration Systems. Water Pollution Control, volume 74. Pages 645 - 656.

⁵⁶Suominen, A. 1980. Puhtaan hapen käyttö aktiivilietemenetelmässä. Vesitalous, volume 21. Pages 14 - 15.

⁵⁷Gray, N F. 1990. Activated Sludge, Theory and Practice. New York, Oxford University Press. Pages 117 - 119.

⁵⁸Sidwick, J M, Lewandowski, T P & Allum, K H. 1975. An Economic Study of the Unox and Conventional Aeration Systems. Water Pollution Control, volume 74. Pages 645 - 656.

⁵⁹Anon. 1988. Aeration. Manual of Practice FD - 13. Water Pollution Control Federation. Page 154.

closed oxygen rich atmospheres which generally employ surface aerators, and open systems which employ fine bubble diffusers⁶⁰.

With the closed multistage contacting system, the basins are covered. The oxygen feed gas is introduced in the first stage. Successive stages are connected by ports at the surface to allow gas to flow from stage to stage. Exhaust gases are removed by venting from the last stage⁶¹. The best known closed basin system is called Unox and it is illustrated in Figure 13. Aeration is performed by surface aerators.

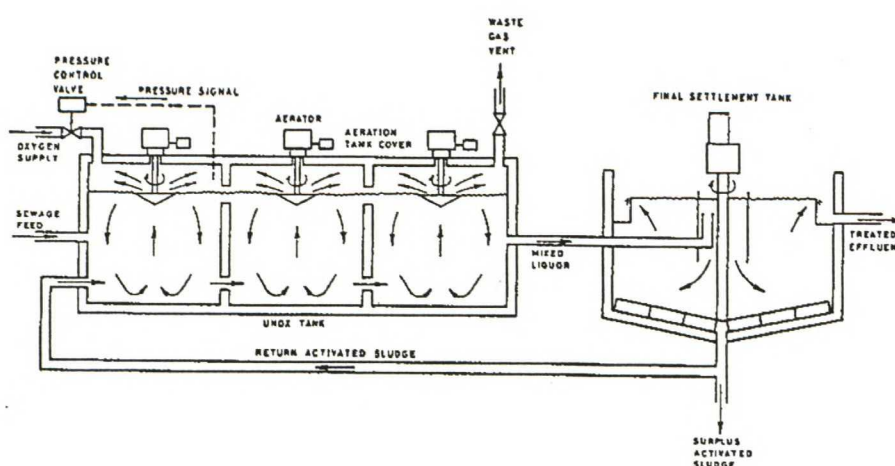


Figure 13. Unox closed basin high purity oxygen system⁶²

With the open basin system, oxygen control results from monitoring dissolved oxygen in the mixed liquor and controlling the oxygen supply to the aeration equipment that dissolves the oxygen⁶³. This is illustrated in Figure 14. Disc diffusers, rotating porous discs, and submerged turbine aerators can be used as aeration equipment.

⁶⁰Gray, N F. 1990. Activated Sludge, Theory and Practice. New York, Oxford University Press. Page 119.

⁶¹Water Pollution Control Federation. 1988. Aeration. Manual of Practice FD - 13. Page 155.

⁶²Sidwick, J M, Lewandowski, T P & Allum, K H. 1975. An Economic Study of the Unox and Conventional Aeration Systems. Water Pollution Control, volume 74. Page 645.

⁶³Anon. 1988. Aeration. Manual of Practice FD - 13. Water Pollution Control Federation. Page 156.

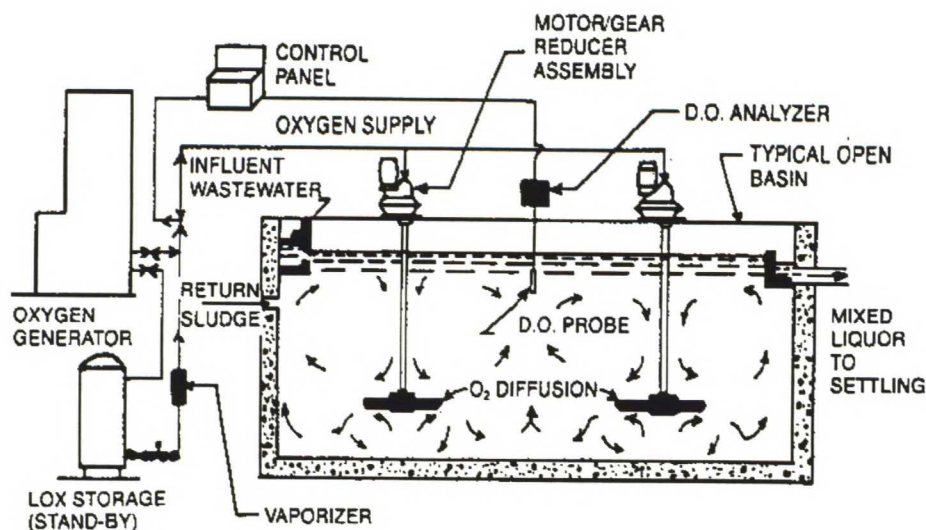


Figure 14. Open basin high purity oxygen system⁶⁴

Praxair, Inc. produces surface aerators which use pure oxygen in open basins. These aerators are called In-Situ Oxygenators⁶⁵, see Figure 15.

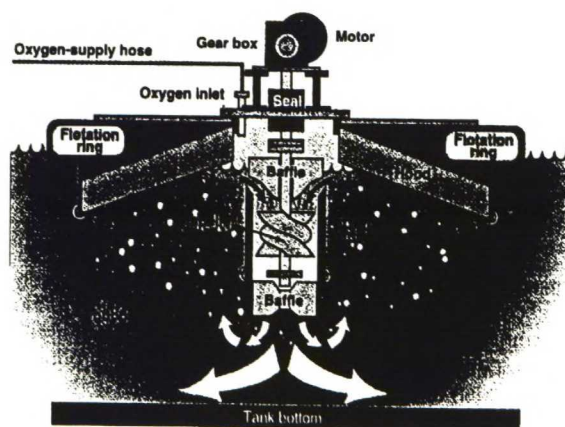


Figure 15. In-situ oxygenator⁶⁶

The downward-pumping impeller creates high shear and suction in a draft tube. As oxygen is injected in the headspace beneath the hood, the circulating water entrains it, discharging oxygenated water at the floor of the aeration

⁶⁴Anon. 1988. Aeration. Manual of Practice FD - 13. Water Pollution Control Federation. Page 155.

⁶⁵Anon. 1994. In Situ Oxygenator Improves Wastewater Treatment. Environmental Engineering, a special supplement to September 1994 Chemical Engineering. Pages EE 26 - 27.

⁶⁶Anon. 1994. In Situ Oxygenator Improves Wastewater Treatment. Environmental Engineering, a special supplement to September 1994 Chemical Engineering. Page EE 26.

basin. The offgas-collection hood captures undissolved oxygen, and returns it to the draft tube. This minimises the total volume of makeup oxygen that is required.

2.2 Aeration Equipment Not Using Compressed Air

Aspirating Aerators

The most common aspirating aerator consists of a motor driven aspirator pump, see Figure 16. The pump draws in air through a hollow tube and injects it underwater, where both high velocity and propeller action create turbulence and diffuse the air bubbles. The aspirating device can be mounted on a fixed structure or on pontoons⁶⁷. Operation of aspirating devices in very cold weather has been reported to be a problem because the aspirator pipe can ice up at the surface, shutting off the air supply⁶⁸.

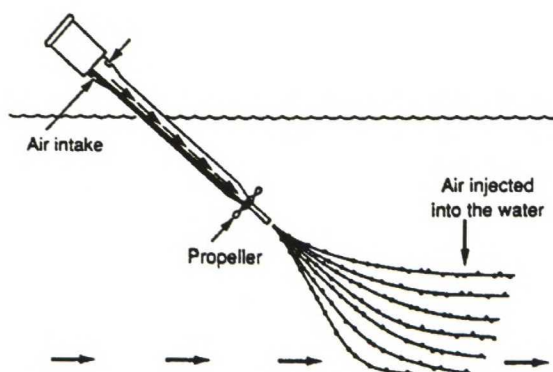


Figure 16. Aspirating aerator⁶⁹

Aire-O₂ of Aeration Industries International, Inc. and Oxygun are well-known aspirating aerators. Frings and Gebr. Maier have also several models which are self-aspirating. These can be placed on the bottom of the aeration basin when the basins are shallow enough.

⁶⁷Tchobanoglous, G. 1991. Wastewater Engineering: Treatment, Disposal, and Reuse. Singapore, McGraw-Hill. Page 561.

⁶⁸Anon. 1988. Aeration. Manual of Practice FD - 13. Water Pollution Control Federation. Page 31.

Low-speed surface aerators with vertical axis

Surface aeration achieves aeration and mixing by the use of blades or vanes which are rotated at speed. The aerator, which rotates about a vertical or horizontal shaft, is positioned at or near the surface of the liquid in the aeration basin⁷⁰. It seems that surface aerators are losing in popularity⁷¹. Bottom aerators have in practice surpassed surface aerators in biological nutrient removal processes. For example, control of the oxygen supply is easier with bottom aerators than with large surface aerators. Another disadvantage of surface aerators is the variation in oxygen concentration along the depth of the basin, which makes control more difficult⁷².

It has been shown⁷³ that surface aerators do not encourage nitrification as effectively as the diffusers do. When oxygen is supplied from a single source, such as a surface aerator, the activated sludge has to be provided with a relatively high concentration of oxygen. This is to allow for uptake during the time that the sludge remains in the deeper regions of the basin. Studies⁷⁴ suggest that surface aeration may be more cost-effective than diffused air. However, similar studies have indicated that where nitrification is required, a diffused air plant could be preferable.

Control of dissolved oxygen concentrations with surface aerators is more difficult than with diffusers. The fairly common dissolved oxygen meter

⁶⁹Tchobanoglous, G. 1991. Wastewater Engineering: Treatment, Disposal, and Reuse. Singapore, McGraw-Hill. Page 559.

⁷⁰Chambers, B & Jones, G L. 1988. Optimisation and Upgrading of Activated Sludge Plants by Efficient Process Design. Water Science & Technology, volume 20, 4/5. Pages 121 - 132.

⁷¹Ruokonen, M. 1996. Aeration Equipment in Biological Waste Water Treatment. Helsinki University of Technology, Faculty of Forest Products Technology, Laboratory of Environmental Protection Technology, Special Study. Pages 74 - 81.

⁷²Ojanen, M. 1994. Biologisen ravinteidenpoiston tekniikka. Helsinki University of Technology, Laboratory of Sanitary and Environmental Engineering, Master's Thesis. Page 58.

⁷³Maier, W & Krauth, Kh. 1988. Optimizing Nitrification in Aeration Basins with Surface Aerators. Water Science & Technology, volume 20, 4 - 5. Pages 23 - 28.

⁷⁴Ainsworth, G & Gill, T. 1987. The Activated-Sludge Process: What Would Fowler, Ardern and Lockett Say Now? Water Pollution Control, volume 86. Pages 220 - 234.

control of adjustable outlet weirs, to regulate overall aerator submergence, has proved a relatively coarse method. Another method of control is differential setting of the jacking screws on the aerators, coupled with provision for incremental feed of settled sewage to the beginning of the basin. Dissolved oxygen control has also been achieved by variable or multi-speed drives to the aerators. However, the cheapest and most convenient method practised has been the intermittent switching-off of selected aerators at high dissolved oxygen levels, usually incorporating a timer override.

The performance of any type of surface aerator will, at least to some degree, be dependent on the geometry of the basin, as well as on the nature of the water or mixed liquor⁷⁵.

The vertical shaft aerator is the most widely used aeration method⁷⁶. Surface aerators with vertical axis are usually divided into low-speed, medium-speed, and high-speed aerators. The speed of low-speed aerators is approximately 20 - 60 rpm and that of high-speed aerators 300 - 1,200 rpm. A typical low-speed surface aerator is presented in Figure 17.

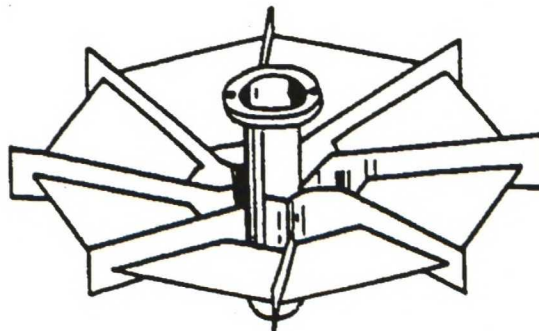


Figure 17. Mechanical aerator with disc-type impeller and radial blades⁷⁷

⁷⁵Wheatland, A B & Boon, A G. 1979. Aeration and Oxygenation in Sewage Treatment - Some Recent Developments. Progress in Water Technology, volume 11, 3. Pages 171 - 179.

⁷⁶Gray, N F. 1990. Activated Sludge, Theory and Practice. New York, Oxford University Press. Page 58.

⁷⁷Anon. 1988. Aeration. Manual of Practice FD - 13. Water Pollution Control Federation. Page 77.

Surface low-speed aerators are suitable for all the activated sludge processes and for aerated lagoons. The capacities are usually not greater than 50 000 m³/d in these plants⁷⁸. These aerators were first used predominantly in complete-mix aeration basins at conventional or high loading rates. Later, they were also applied to low rate processes such as extended aeration. Variable mounting is available as a fixed platform, a walk way, or a raft. Raft-mounted units allow for wide liquid-level variations and for periodic aerator towing for inspection. For efficient mixing and aeration, pontoons are designed to eliminate interference with generated hydraulic patterns⁷⁹.

Aeration efficiency and capacity are relatively good, as well as the mixing capacity. The use of centrifugal aerators does not restrict the basin design in any way. This kind of aerator can freeze in the winter. A drive-ring hood for preventing ice accumulation in all but extreme cold weather conditions is available⁸⁰. The investment cost of low-speed aerators is higher than that of the high-speed aerators. The gear mechanism causes a lot of maintenance work⁸¹.

The Oxyrator, Simplex, and Simcar are examples of low-speed surface vertical axis aerators. Simplex is manufactured by Ames Crosta Babcock. Simcar is produced by Simon & Hardley. The Dutch contracting company Landustrie has a model called Landy.

⁷⁸Anon. 1988. Aeration. Manual of Practice FD - 13. Water Pollution Control Federation. Page 93.

⁷⁹Anon. 1988. Aeration. Manual of Practice FD - 13. Water Pollution Control Federation. Page 76.

⁸⁰Anon. 1988. Aeration. Manual of Practice FD - 13. Water Pollution Control Federation. Page 78.

⁸¹Kiiskinen, S. 1986. Ilmastuslaitteet. In: Kiiskinen, S, Lindqvist, H, Noukka, K, Rantala, P, Tantt, U & Viikari, P. Jäteveden puhdistuksen uudet menetelmät ja laitteet. Helsinki, INSKO 184 - 86. Pages XIII 1 - 20.

Medium-speed aerators

Medium-speed aerators are also called radial-axial vertical surface aerators. They comprise an impeller and a motor-gear assembly. Typical impellers are either inverted cone bodies with curvilinear vanes or open blades attached to a circular frame or a drive shaft. These impellers can be used with or without a shroud and draft tube. The rotational speeds of radial-axial aerators are greater than those of centrifugal aerators, although the reduction gears are smaller and the aerators are lighter⁸². The radial-axial submerged-turbine aerator is displayed in Figure 18.

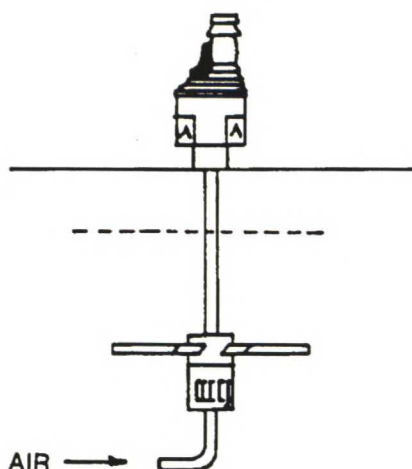


Figure 18. Radial axial submerged-turbine aerator⁸³

High-speed aerators

High-speed surface aerators were first used in aerated ponds and lagoons. Presently, this type of aerators are also used in various modifications of the activated sludge process. Many pulp and paper mills have chosen high-speed surface aerators^{84,85}. The plant capacities may reach 50 000 m³/d. The

⁸²Anon. 1988. Aeration. Manual of Practice FD - 13. Water Pollution Control Federation. Page 77.

⁸³Anon. 1988. Aeration. Manual of Practice FD - 13. Water Pollution Control Federation. Page 78.

⁸⁴Lehtonen, J. 1994. Jäteveden puhdistuksen kehitys Suomessa pitkällä aikavälillä. Tampere, Tampere University of Technology, Institute of Water and Environmental Engineering. Page 75 - 77.

aeration basin shape may be either circular or square. Because high-speed aerators are of light weight, they are often mounted on floats. This is especially convenient for lagoon applications where the water level may change substantially. Wave action is also a factor that should not be forgotten⁸⁶.

High-speed aerators are liftable, and have low initial and installation costs which makes them relatively easy to add to an existing system. Their disadvantages include a lower aeration efficiency and a poor mixing capability compared to low-speed surface aerators. In cold climates, high-speed aerators produce greater cooling of the aerated liquid than the low-speed aerators, thus reducing biological activity. Icing of the floating unit may occasionally result in capsizing; therefore, flotation stability should be considered⁸⁷.

One type of a high-speed surface aerator is shown in Figure 19. It is an axial-flow, vertical-axis aerators with a propeller-type impeller driven by a motor without a gear box, a shroud in which the impeller is located, and a flow-directing casing. The design of this casing determines the direction of the liquid jets discharged from the aerator: upwards and away from the aerator, horizontal from the aerator, and downwards and away from the aerator. The discharge jets partially break into droplets, then entrain and disperse the air into bubbles on impingement into the bulk liquid in the vessel. The large surface area of droplets and bubbles ensures an effective oxygen transfer rate. Large flow rates developed by the aerator impeller provide a high mixing level and biomass suspension⁸⁸. AquaSystems International produces

⁸⁵Springer, A M. 1986. Industrial Environmental Control, Pulp and Paper Industry. New York, John Wiley & Sons. Page 231.

⁸⁶Anon. 1988. Aeration. Manual of Practice FD - 13. Water Pollution Control Federation. Page 94.

⁸⁷Anon. 1988. Aeration. Manual of Practice FD - 13. Water Pollution Control Federation. Page 94.

⁸⁸Anon. 1988. Aeration. Manual of Practice FD - 13. Water Pollution Control Federation. Pages 78 - 79.

high-speed surface aerators called AquaTurbo. These can be used only in shallow basins; the water depth should be less than 4 m.

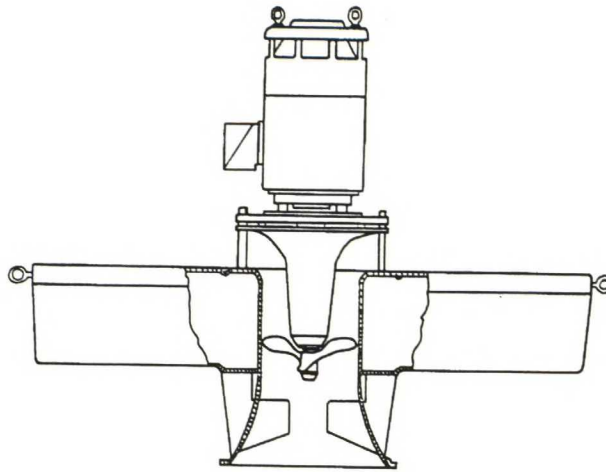


Figure 19. High-speed aerator⁸⁹

Brush aerator

Brush aerators are surface mechanical aerators with a horizontal axis. Original brush-type aerators, known as the Kessener aerators, had a horizontal cylinder rotor with bristles submerged in the bulk liquid of the vessel, approximately to half the diameter. The system is shown in Figure 20. Now, angle steel, steel of other shapes, or plastic bars are used instead of bristles. There are not many manufacturers of brush aerators. At 11. International Trade Fair for Waste Water and Waste Disposal in München in May 1996, there were only two companies, Passavant and Landustrie, marketing them.

⁸⁹Anon. 1988. Aeration. Manual of Practice FD - 13. Water Pollution Control Federation. Page 80.

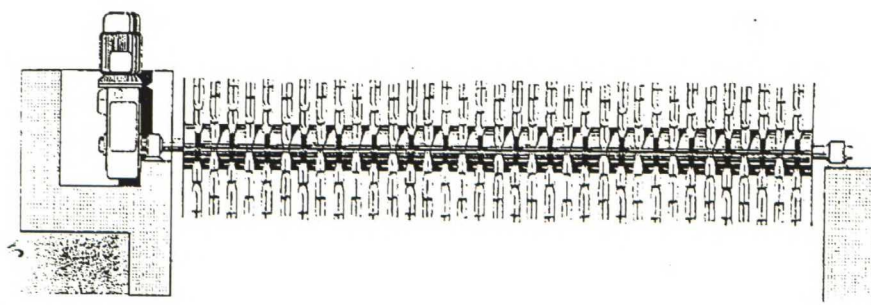


Figure 20. Brush aerator⁹⁰

When the aerator is driven by a motor, the bars or blades drive the air into the water, and throw water jets and droplets into the air. This results in oxygen diffusing into the air-water interface. Simultaneously, the liquid is propelled by the rotor, which provides mixing in the vessel. Enclosures over the top section of the aerator are used to reduce mist and droplet dispersion into the air and to prevent or reduce the freezing problem⁹¹. The brush aerators are also called cage or paddle rotors. Passavant, with its Mammoth rotor, has a system where several brushes have been mounted together on one floating pontoon.

Brush aerators are generally used at small to medium sized plants operated as extended aeration systems, like in oxidation ditches⁹². The aerators are capable of propelling the liquid in the aeration channel at a substantial velocity, 0.3 to 0.6 m/s. In cold climates, winter operation presents a problem because of mist and freezing droplets. This may be partially alleviated by the use of aerator enclosures⁹³.

The investment cost is not high, and brush aerators are easy to install and use. Maintenance is also simple. Aeration efficiency is relatively good but the

⁹⁰GTA product brochure.

⁹¹Anon. 1988. Aeration. Manual of Practice FD - 13. Water Pollution Control Federation. Pages 86 - 87.

⁹²Gray, N F. 1990. Activated Sludge, Theory and Practice. New York, Oxford University Press. Page 64.

⁹³Anon. 1988. Aeration. Manual of Practice FD - 13. Water Pollution Control Federation. Page 95.

system is not very flexible⁹⁴. Brush aerators cannot be used in very deep basins, 2 - 4 m is the economical optimal depth⁹⁵.

⁹⁴Kiiskinen, S. 1986. Ilmastuslaitteet. In: Kiiskinen, S, Lindqvist, H, Noukka, K, Rantala, P, Tantt, U & Viikari, P. Jäteveden puhdistuksen uudet menetelmät ja laitteet. Helsinki, INSKO 184 - 86. Pages XIII 1 - 20.

⁹⁵von der Emde, W. 1979. Criteria for Selecting Aeration Systems. Progress in Water Technology, volume 11, 3. Pages 201 - 203.

3 Customers

In this study, a customer is defined as a person to whom the characteristics of the product are important or who sets requirements for the product. By this definition, one can identify various customers of an aeration equipment manufacturer. Research centres, municipal authorities, plant operators, consultants, contractors and distributors are among the customers of the aeration equipment manufacturer.

The buying process for investment goods is long and complicated. Many people are involved in the decision making, and it may be difficult to identify the real decision makers. The decision making unit of a buying organisation can be called a buying centre⁹⁶. It is defined as all those individuals and groups who participate in the purchasing decision making process, who share some common goals, and the risks arising from the decisions. The buying centre includes all members of the organisation who play any of the following roles in the purchase decision process:

1. *users* are those who actually use the purchased products and services but who may have little or no buying authority and varying amounts of buying influence. In many cases, the users initiate the buying proposal and help define the product specifications.
2. *influencers* do not necessarily have buying authority but can influence the outcome of the decision through the application of constraints. They often help define specifications and provide information for evaluating alternatives. Technical personnel are particularly important as influencers.
3. *deciders* are persons who decide on product requirements and / or supplier.

⁹⁶Webster, F E Jr & Wind, Y. 1972. Organizational Buying Behavior. Englewood Cliffs, Prentice-Hall, Inc. Page 6.

4. *approvers* are persons who authorise the proposed actions of deciders and buyers.
5. *buyers* are persons with formal authority for selecting the supplier and arranging the terms of purchase. Buyers may help shape product specifications, but they play their major role in selecting vendors and negotiating. In more complex purchases, the buyers might include high-level officers participating in the negotiations.
6. *gatekeepers* are persons who control the flow of information into the buying group. For example, purchasing agents, receptionists, and telephone operators may prevent sales persons from contacting users or deciders^{97,98}.

In the decision making process for aeration equipment, the buying centre consists of many persons from several organisations. In municipal projects, these organisations include municipal council, municipal waste water authorities, consultants and contracting companies. Plant operators and municipal experts usually work in the organisation of the waste water authority. Consulting and contracting companies have their own buying centres as well. In industrial projects, the buying centre consists of fewer organisations. Sometimes only the persons of the industrial company are involved, but often consulting and contracting companies participate in the decision making process.

⁹⁷Kotler, P. 1991. Marketing Management: Analysis, Planning, Implementation, and Control. Seventh edition. Englewood Cliffs, Prentice Hall, Inc. Pages 200 - 201.

⁹⁸Webster, F E Jr & Wind, Y. 1972. Organizational Buying Behavior. Englewood Cliffs, Prentice-Hall, Inc. Pages 35 - 36.

The seller should identify

- who are the major decision participants
- what decisions do they influence
- what is their level of influence
- what evaluation criteria does each participant use^{99,100}

Major influences on industrial buyers are economic and personal. Price, best product, and best service are economic factors. Favours, attention, and risk avoidance are personal factors^{101,102}.

The customers of the aeration equipment manufacturer are presented below and their role in the decision making process is explained. The customers have partly different needs. In this chapter, the customer groups are described. In the following chapter, the factors affecting the selection of aeration equipment are defined, and the relation between these factors and the customer groups is explained.

Research centres

The research centres affect the aeration equipment decision indirectly. They act as gatekeepers and influencers as they supply research results for the real decision makers. Technische Hochschule in Darmstadt, Environmental Protection Agency in the United States, Technical Research Centre of Finland, and Finnish Environment Institute are examples of important research centres in the field of waste water treatment. Research centres

⁹⁹Kotler, P. 1991. Marketing Management: Analysis, Planning, Implementation, and Control. Seventh edition. Englewood Cliffs, Prentice Hall, Inc. Page 201.

¹⁰⁰Webster, F E Jr & Wind, Y. 1972. Organizational Buying Behavior. Englewood Cliffs, Prentice-Hall, Inc. Page 6.

¹⁰¹Kotler, P. 1991. Marketing Management: Analysis, Planning, Implementation, and Control. Seventh edition. Englewood Cliffs, Prentice Hall, Inc. Page 201.

¹⁰²Webster, F E Jr & Wind, Y. 1972. Organizational Buying Behavior. Englewood Cliffs, Prentice-Hall, Inc. Page 7.

develop new processes and aeration methods, and promote old ones in seminars and in discussions with the real decision makers.

Municipal council

Municipal authorities can act in the same way as research centres in industrial projects giving regulations, but they are often decision makers in municipal projects. There are many customers in a municipality. The engineering or technical office might decide on the selection, but the local municipal council can sometimes be the final decision maker. The municipal council acts mainly as the approver. Since the municipal council only approves the decision made by the other people involved, the effect of the municipal council can be regarded as minimal in the process of selecting aeration equipment, and it is not handled more in depth in this study.

Municipal experts

Municipal experts are usually found in the engineering or technical office of the municipality. The expert can give advise to the local council, and sometimes he or she can choose the supplier without the council. Experts are usually not the end-users of the aeration equipment. Municipal experts can be buyers, influencers, deciders, and approvers.

Industrial experts

The industrial expert is the person in the organisation of an industrial company who defines the product specifications and may also finally decide on the aeration equipment. He or she is usually not the end user of the product. Industrial experts act as deciders, buyers, approvers, and influencers.

Plant operators

Plant operators are the end users of aeration equipment. They are seldom real decision makers but they can often give their opinion. Plant operators are nowadays more qualified than previously which means that they are

respected more, and they are listened to. Plant operators in municipal plants are really qualified in many countries, like in Finland. Plant operators in industrial plants are often less qualified than their colleagues in municipal plants.

Consultants

Consultants are companies that design the waste water treatment plant. Soil and Water is an example of a consulting company. Consultants have much power in the decision making process, in municipal as well as in industrial projects. They can produce tenders which are specified for a certain kind of aeration equipment, and they can design the plant in such a way that some aeration equipment is more advantageous than others. Sometimes consultants evaluate offers and make a proposal to the investor.

A consultant company is a separate buying centre with influencers, buyers, etc. but it also participates in the industrial and municipal buying centres as influencer, buyer, gatekeeper and decider, depending on the project.

Contractors

Contractors are usually companies that construct the waste water treatment plant according to the tender documents. Generally, the contractor replies to the tender given by a consultant. Often the contractor decides on the aeration equipment used. Contractors use subcontractors for supplying the products needed. Contractors and / or subcontractors are customers of the aeration equipment manufacturer when they select the aeration equipment supplier.

A contracting company is also a buying centre in its own right where the seller has to identify the users, influencers, etc. The contractor participates in the industrial and municipal buying centres as well. Contractors are usually deciders, influencers, gatekeepers or buyers. In the case of a commission contract, the contractor is also the end user.

Many contractors develop their own processes in order to differentiate themselves from their competitors. It is important to be aware of this

research work, and to take care that the company's aeration equipment is suitable for the processes developed by the contractors.

Contractor and consultant can also be the same company. In turn key projects, the contractor supplies an entire waste water treatment plant which is ready for operation. Sometimes a commission contract is signed, which means that the contractor also operates the plant for a given time. Contractors are often price squeezers who want to improve their margins.

Distributors

Distributors are companies that sell the products of the aeration equipment manufacturer in a given country. Usually they represent various waste water treatment equipment. They are customers in the sense that the product has to be sold to them before they start marketing the aeration equipment in their territories. Even if the distributors form a team with the equipment manufacturer to market the products together, distributors are real customers in the sense that the manufacturer invoices the distributors.

4 Factors Affecting the Selection of Aeration Equipment

4.1 Process Related Factors

Kotler¹⁰³ divides the competitors into four classes:

- desire
- generic
- form
- brand competitors

Desire competitors of aeration equipment are other waste water treatment methods which fulfil the desire to purify waste water, for example anaerobic methods. Sometimes a process is chosen which does not require any aeration at all. Anaerobic processes are like that. Anaerobic processes and advanced treatment methods, such as membrane technology, adsorption, ozonisation, oxidation, and slow sand filters, are gradually gaining in popularity¹⁰⁴.

Aeration equipment with and without compressed air is a generic competitor. It represents different basic ways of satisfying the same desire. Process selection eliminates to a great extent the desire and generic competitors.

The selected waste water treatment process limits the alternatives for aeration equipment selection. Usually the waste water treatment process is decided upon first, and then the disadvantages and advantages of various

¹⁰³Kotler, P. 1991. Marketing Management: Analysis, Planning, Implementation, and Control. Seventh edition. Englewood Cliffs, Prentice Hall, Inc. Pages 133 - 134.

¹⁰⁴Ruokonen, M. 1996. Aeration Equipment in Biological Waste Water Treatment. Helsinki University of Technology, Faculty of Forest Products Technology, Laboratory of Environmental Protection Technology, Special Study. Pages 73 - 80.

aeration equipment alternatives in this process are evaluated. The tender is then open for the manufacturers of suitable aeration equipment.

Table 2 shows which aeration equipment suits which modifications of the activated sludge process. All the modifications require some kind of aeration but the needs are different for different processes. For example, brush aerators are mainly used in oxidation ditches¹⁰⁵.

The activated sludge process with its many modifications seems to be set to maintain its position as the most common waste water treatment method in the future as well. Biological nutrient removal processes, which are generally modifications of the activated sludge process, are becoming increasingly popular. Biological nitrogen removal processes require intermittent aeration and mixing without aeration, which place new requirements on the aeration equipment.

Often the type of aeration equipment is defined in detail in the tender, so that diffuser manufacturers do not compete with mechanical aerator manufacturers, for example. Processes that require high aeration efficiency need aeration equipment with compressed air. In the tender phase, product, company, and service factors are dominant. Local factors are also of importance. In some cases the tender is so detailed beforehand that only one manufacturer has a chance to make an offer. This is a typical situation in the United States, China, and in many Asian countries.

¹⁰⁵Springer, A M. 1986. Industrial Environmental Control, Pulp and Paper Industry. New York, John Wiley & Sons. Page 231.

Table 2. Aeration equipment and activated sludge process modifications¹⁰⁶

● common ○ suitable

	Aeration equipment with compressed air													Aeration equipment without compressed air					
	Plate diffuser	Tube diffuser	Dome diffuser	Disc, ceramic	Disc, plastic	Disc, membrane	Porous rotating disc	Valved orifice diffuser	Fixed orifice diffuser	Static tube aerator	Perforated hose	Jet aerator	Turbine aerator with compressed air	Aspirating aerator	Turbine aerator without compressed air	Surface high-speed aerator	Surface low-speed	Surface medium-speed	Brush aerator
Conventional activated sludge	○	○	●	●	●	●	○	○	○	○	○	●	●	○	○	●	●	○	○
Tapered aeration			●	●	●	●							○						
Step feed		○	●	●	●	●													
Incremental sludge feeding			○	○	○	○							○						
Completely mixed activated sludge			○	○	○	○						○	●						
Extended aeration			○	○	○	○													●
Oxidation ditch			○	○	○	○					○	○				○	○	○	●
Carrousel process																○	○	○	○
High rate activated sludge													○			○	○	○	○
A-B process		○	○	○	○	○													
Contact stabilization			○	○	○	○													
Kraus process				○	○	○							○						
Hatfield process				○	○	○													
Sequencing batch reactor						○						●	○						
N-D process						●						○	○						
D-N process						●						○	○						
D-N-D process						●						○	○						
Simultaneous denitrification						●							○						
A/O process				●	●	●													
PhoStrip				○	○	○													
Bardenpho				○	○	○													
UCT process				○	○	○													
Three-stage Phoredox and A2O				○	○	○													
Biodenitro						○													
Biodenipho						○													
Deep shaft						○													
FM-AS process				○	○	○													
Multireactor				○	○	○													
Closed basin pure oxygen																○	○	○	
Open basin pure oxygen				○	○	○	○					○	○						
Aerated lagoon										○	○	●				○	○	○	●

Waste water characteristics¹⁰⁷ affect the choice of aeration equipment. Some materials are sensitive to certain chemicals. The type of waste water is

¹⁰⁶Ruokonen, M. 1996. Aeration Equipment in Biological Waste Water Treatment. Helsinki University of Technology, Faculty of Forest Products Technology, Laboratory of Environmental Protection Technology, Special Study. Page 83.

important. Often the industrial applications require a different kind of aeration equipment than the municipal ones. The pollutant concentration of waste water is significant, too. There is a clear trend for less waste water per population equivalent to be produced. The concentration is then higher in domestic waste water. In industrial installations, concentrations are becoming higher because of internal water recycling¹⁰⁸. It seems that, by the year 2005, the zero-effluent pulp mill will be realised¹⁰⁹. Porous diffusers do not suit demanding industrial waste waters¹¹⁰. Water temperature can also impose restrictions on aeration equipment. The sludge content is a further factor.

The plant capacity is another factor. The larger plants seem to apply air diffusers more often while the smaller plants prefer to use surface aerators because they do not require so much maintenance and technical skill¹¹¹. There is a tendency to construct larger plants¹¹². However, smaller plants will also be built continuously. The variability in the flow rate is a process related factor. If the flow rate varies a lot, an aeration system which is flexible should be chosen. The shape and size of the aeration basin also place limits on the aeration equipment. Often the round basins are more favourable to surface aerators than the rectangular basins. There is a strong trend to

¹⁰⁷Anon. 1988. Aeration. Manual of Practice FD - 13. Water Pollution Control Federation. Page 93.

¹⁰⁸Ruokonen, M. 1996. Aeration Equipment in Biological Waste Water Treatment. Helsinki University of Technology, Faculty of Forest Products Technology, Laboratory of Environmental Protection Technology, Special Study. Page 79.

¹⁰⁹Meadows, D G. 1995. The Pulp Mill of the Future: 2005 and Beyond. Tappi Journal, volume 78, 10. Pages 55 - 60.

¹¹⁰Kiiskinen, S. 1986. Ilmastuslaitteet. In: Kiiskinen, S, Lindqvist, H, Noukka, K, Rantala, P, Tanttu, U & Viikari, P. Jäteveden puhdistuksen uudet menetelmät ja laitteet. Helsinki, INSKO 184 - 86. Pages XIII 1 - 20.

¹¹¹Chambers, B & Jones, G L. 1988. Optimisation and Upgrading of Activated Sludge Plants by Efficient Process Design. Water Science & Technology, volume 20, 4/5. Pages 121 - 132.

¹¹²Ruokonen, M. 1996. Aeration Equipment in Biological Waste Water Treatment. Helsinki University of Technology, Faculty of Forest Products Technology, Laboratory of Environmental Protection Technology, Special Study. Page 80.

construct deeper basins to reduce the space required¹¹³. Deep basins set requirements for aeration equipment.

Form and brand competitors come into play after the desire and generic competitors. Different aeration methods, such as tube and disc diffusers, and turbine aerators, are form competitors. Brand competitors are aeration equipment that is similar but which has different manufacturers, such as the disc diffusers of Nopon Oy and Sanitaire. The selection between two brand competitors is mostly based on service, company, and local factors. Where there is substantial similarity in supplier offers, industrial buyers have little basis for rational choice¹¹⁴. Here, the aeration manufacturer has either to differentiate the product, to lower the price, or to concentrate in improving the personal factors in marketing.

The process related factors are not really of interest to this study since the aeration equipment manufacturer cannot affect the choice to any great extent. Of course, the aeration equipment manufacturer has to be aware of the developments in waste water treatment processes so that a situation will not arise where there is no market for the company's products. However, more emphasis should be placed on the product, service, cost, and company related factors since these are the sectors where the company can improve its performance. In Figure 21, the process related factors that have been defined in this study are presented.

¹¹³Ruokonen, M. 1996. Aeration Equipment in Biological Waste Water Treatment. Helsinki University of Technology, Faculty of Forest Products Technology, Laboratory of Environmental Protection Technology, Special Study. Pages 76 - 77.

¹¹⁴Kotler, P. 1991. Marketing Management: Analysis, Planning, Implementation, and Control. Seventh edition. Englewood Cliffs, Prentice Hall, Inc. Page 202.

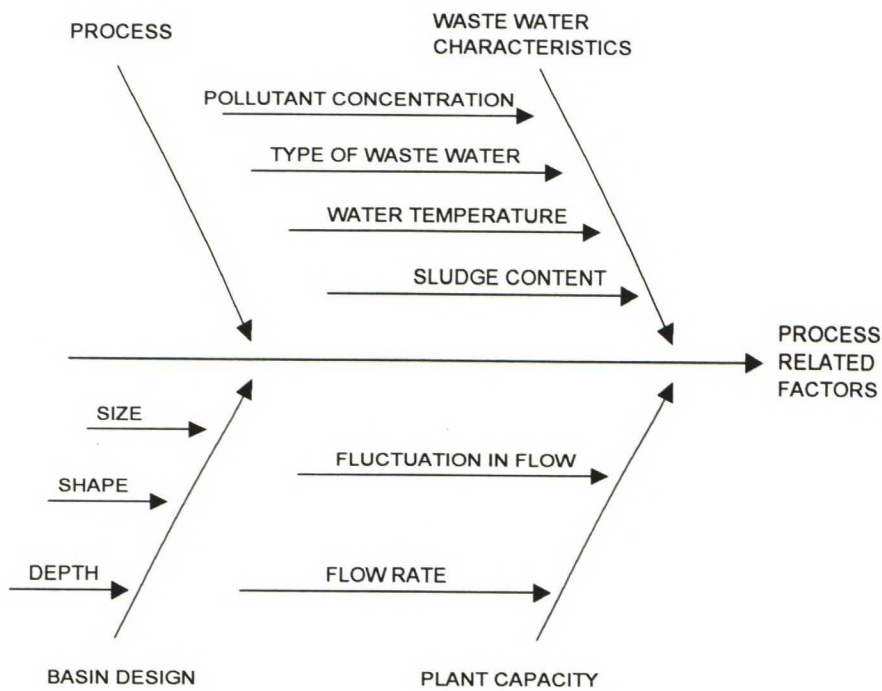


Figure 21. Factors related to the process

Research centres, municipal and industrial experts, consultants and contractors can affect the selection of the waste water treatment process. Research centres and contractors develop new processes. Municipal and industrial experts and consultants decide primarily whether the new processes are actually used. The basin design can be influenced by consultants, contractors, research centres, and experts. Plant capacity and waste water characteristics are basically given parameters which cannot be changed.

4.2 Product Related Factors

The product related factors which affect the selection of aeration equipment can be divided into product features which produce good effluent quality, low operation costs, low investment costs, and minimal risks. Here the form and brand competitors of Nopol® aeration equipment are considered. This means that aeration equipment without compressed air is generally not involved here.

Good effluent quality

The customer receives good effluent quality if the aeration system is reliable, the desired dissolved oxygen level is achieved, and no sludge sedimentation occurs in the aeration basin.

The reliability is affected by the materials the equipment is made of, and by the possibility to operate continuously, without having to stop for maintenance. Since the emission restrictions are becoming stricter^{115,116}, there is a clear trend towards more reliable aeration equipment. The disposal of untreated waste water is not allowed even during maintenance.

For the judgement of the reliability of an aeration system the complete system, including all components, like blowers and connecting pipes, has to be taken into consideration¹¹⁷. Generally, with mechanical aerators, the reliability is mostly related to the gear unit quality¹¹⁸. Lifiable equipment is considered more reliable than fixed equipment since the process does not have to be interrupted for reparation and maintenance.

Clogging is a serious problem related to aeration. Aeration equipment which does not tend to clog is more reliable, and easier to operate and maintain. Diffusers face problems with clogging more often than mechanical aerators.

The achieved dissolved oxygen concentration is affected by aeration efficiency and peak load conditions. For disc diffusers, the product features that are important are basin bottom coverage, disc diffuser density, operation range, and possibility of tapering the diffusers.

¹¹⁵Ruokonen, M. 1996. Aeration Equipment in Biological Waste Water Treatment. Helsinki University of Technology, Faculty of Forest Products Technology, Laboratory of Environmental Protection Technology, Special Study. Page 78.

¹¹⁶Frey, W. 1992. A Comparison of Different Aeration Systems. Water Science & Technology, volume 25, 4 -5. Pages 143 - 149.

¹¹⁷Frey, W. 1992. A Comparison of Different Aeration Systems. Water Science & Technology, volume 25, 4 -5. Pages 143 - 149.

¹¹⁸von der Emde, W. 1979. Criteria for Selecting Aeration Systems. Progress in Water Technology, volume 11, 3. Pages 201 - 203.

Normally aeration systems are selected by means of standard oxygen transfer efficiency in clean water given by the manufacturer. In day to day operation, however, the efficiency of the system under actual operating conditions is decisive. Questions concerning operational experience, reliability, maintenance, and repair are in most cases not dealt with¹¹⁹.

Sludge sedimentation in the aeration basin is avoided by the right mixing capacity. The distance between diffusers and bottom coverage determinate this for disc diffusers. An external mixer might be required. The influence of the aeration equipment on sludge properties is also important.

Low investment costs

Investment costs are affected by equipment price and installation costs. The equipment price is defined by the aeration equipment price, and by the size and materials of the eventual pipework, compressors, and oxygen generation equipment. Installation costs are affected by installation time, system modularity and preassembled components. If the aeration system is liftable, the installation is possible without interrupting the process.

The selection of aeration equipment can affect the investment costs of the entire waste water treatment plant. Surface aerators, for example, require support bridges.

It is difficult to evaluate the importance of the investment costs because this is the only factor really known when purchasing aeration equipment. Operation costs are only known accurately after the purchase. It is the same with the quality of the product and the service level of the company, which can be evaluated and appreciated only years after the purchase.

¹¹⁹Frey, W. 1992. A Comparison of Different Aeration Systems. Water Science & Technology, volume 25, 4 -5. Pages 143 - 149.

Low operation costs

Energy consumption, lifetime, ease of maintenance and ease of use affect the operation costs. Operation costs are often higher than investment costs. Aeration requires a lot of energy. The need for staff affects the operation costs, too. There can also be a need for chemicals, materials, supplies, and other accessories.

A comparison of the economy of different systems should not only include the costs of construction but also the total costs for a prolonged period, at least for one year. It is very difficult to evaluate aeration costs for treatment plants that not only have different aeration systems, but differ also in size, loading, and effluent quality¹²⁰. In the case of compressed air aeration, where the coupling of blowers with gas machines is provided, no direct comparison can be made with a surface aeration system which does not require compressed air. A real comparison of different aeration systems can only be performed on the basis of yearly costs. This means that the capital and running costs of the whole waste water treatment plant and the purification performance are compared¹²¹.

The aeration efficiency is essential since aeration takes approximately 40 to 90 % of electricity consumption in an activated sludge plant. It is one of the most energy intensive operations in the waste water treatment plant. Most sources^{122, 123} give an approximate value of 45 %. After the energy crisis of

¹²⁰Frey, W. 1992. A Comparison of Different Aeration Systems. Water Science & Technology, volume 25, 4 -5. Pages 143 - 149.

¹²¹von der Emde, W. 1979. Criteria for Selecting Aeration Systems. Progress in Water Technology, volume 11, 3. Pages 201 - 203.

¹²²Evans, B & Laughton, P. 1994. Emerging Trends in Electrical Energy Usage at Canadian (Ontario) Municipal Wastewater Treatment Facilities and Strategies for Improving Energy Efficiency. Water Science & Technology, volume 30, 4. Pages 17 - 23.

¹²³Ojanen, M. 1994. Biologisen ravinteidenpoiston tekniikka. Helsinki University of Technology, Laboratory of Sanitary and Environmental Engineering, Master's Thesis. Page 56.

the early 1970s, aeration systems were developed intensively¹²⁴, but they still use a lot of energy, and the energy consumption should be taken into account when choosing aeration equipment. Saving energy is environmentally friendly, too. There is still a strong trend to decrease energy consumption¹²⁵.

Of course, local costs of energy and labour markedly influence the operation costs.

A long lifetime is achieved by good materials, temperature resistance, chemical resistance, resistance to dynamic loads, and control of peak flows. The ease of retrofitting and extension also affects the expected lifetime. The aeration equipment can be used longer if the system can be expanded and tailored later on according to changes in the waste water.

Maintenance requirements are affected by the need for close monitoring by skilled personnel, frequency of diffuser cleaning or replacement, cost and effort of diffuser cleaning and replacement, material breakages, and by the skill, budget, time and motivation of the personnel. Personnel requirements are affected by the amount of operating and maintenance personnel needed, the skills required, and by the need for training.

Ease of maintenance is becoming increasingly important, since the labour is expensive, and in most of the plants, the amount of staff has been reduced to a minimum. The remaining labour force does not have much time for maintenance¹²⁶. Ease of maintenance is achieved by liftable systems, acid cleaning of diffusers, good component design and component assembly.

¹²⁴Anon. 1988. Aeration. Manual of Practice FD - 13. Water Pollution Control Federation. Page 1.

¹²⁵Ruokonen, M. 1996. Aeration Equipment in Biological Waste Water Treatment. Helsinki University of Technology, Faculty of Forest Products Technology, Laboratory of Environmental Protection Technology, Special Study. Page 79.

¹²⁶Ruokonen, M. 1996. Aeration Equipment in Biological Waste Water Treatment. Helsinki University of Technology, Faculty of Forest Products Technology, Laboratory of Environmental Protection Technology, Special Study. Page 79.

Clogging tendency is important. The gearing of mechanical aerators often requires a lot of maintenance.

Maintenance costs can be high. Some aeration equipment requires more maintenance than others. The need for spare parts, chemicals, other supplies, and reparation varies significantly.

Aeration equipment should be easy to use. Ease of use is affected by operation range controllability and on-off operation.

The operation costs of aeration are considerable. It has happened that the World Bank has financed the construction of a waste water treatment plant for a developing country, but the plant has subsequently never been used because of the operation costs, which have to be paid locally.

Minimal risks

Minimal risks are achieved by selecting equipment which is flexible, which is environmentally friendly, and which is manufactured by a reliable company so that the availability of spare parts is certain.

Flexibility is achieved by the opportunity to extend and reduce the system capacity and to change tapering and lay-out. The adaptation of the aeration equipment for different loading conditions is a prerequisite for economical operation of an activated sludge plant¹²⁷.

Environmental friendliness is achieved by the right selection of materials, and by environmentally friendly operation. Since the disposal of polyvinyl chloride is harmful to the environment, equipment made of this material should be avoided. In some European countries, as in the Netherlands and Germany, there are already regulations that forbid municipalities purchasing polyvinyl chloride components. The materials should be recyclable, like polypropylene. On the other hand, the installation of aeration equipment can

¹²⁷Frey, W. 1992. A Comparison of Different Aeration Systems. Water Science & Technology, volume 25, 4 -5. Pages 143 - 149.

also be injurious to the people and to the environment. For example, some disc diffusers require solvent welding during installation which is a safety problem for the employees.

The operation of aeration equipment can also pose risks. Surface aerators produce aerosols which adversely affect the working environment¹²⁸. A high level of aerosols can be expected from surface aerators with a vertical shaft. Aerosols may be produced as well in the zone of intensive interface removal in surface aerators with a horizontal shaft. If there are urban dwellings nearby, special care has to be taken in respect of the noise level of different aeration systems¹²⁹. Surface aerators often have a higher noise level than bottom aerators. The compression of air produces a lot of noise, too.

The availability of components afterwards is essential. The spare part availability is best ensured by selecting a manufacturer who is economically sound and has long traditions. An aeration system which has standard spare parts which can be bought anywhere is, of course, the best alternative.

Many people have reservations about using proven processes or equipment and not experimenting. There are always risks with new equipment. On the other hand, the manufacturer usually gives a better price to the customer who is willing to test new equipment. The customer can evaluate the soundness of the equipment by analysing the company's reference list, for example.

¹²⁸Ruokonen, M. 1996. Aeration Equipment in Biological Waste Water Treatment. Helsinki University of Technology, Faculty of Forest Products Technology, Laboratory of Environmental Protection Technology, Special Study. Page 79.

¹²⁹von der Emde, W. 1979. Criteria for Selecting Aeration Systems. Progress in Water Technology, volume 11, 3. Pages 201 - 203.

Evaluation

The product related factors are presented in Figure 22.

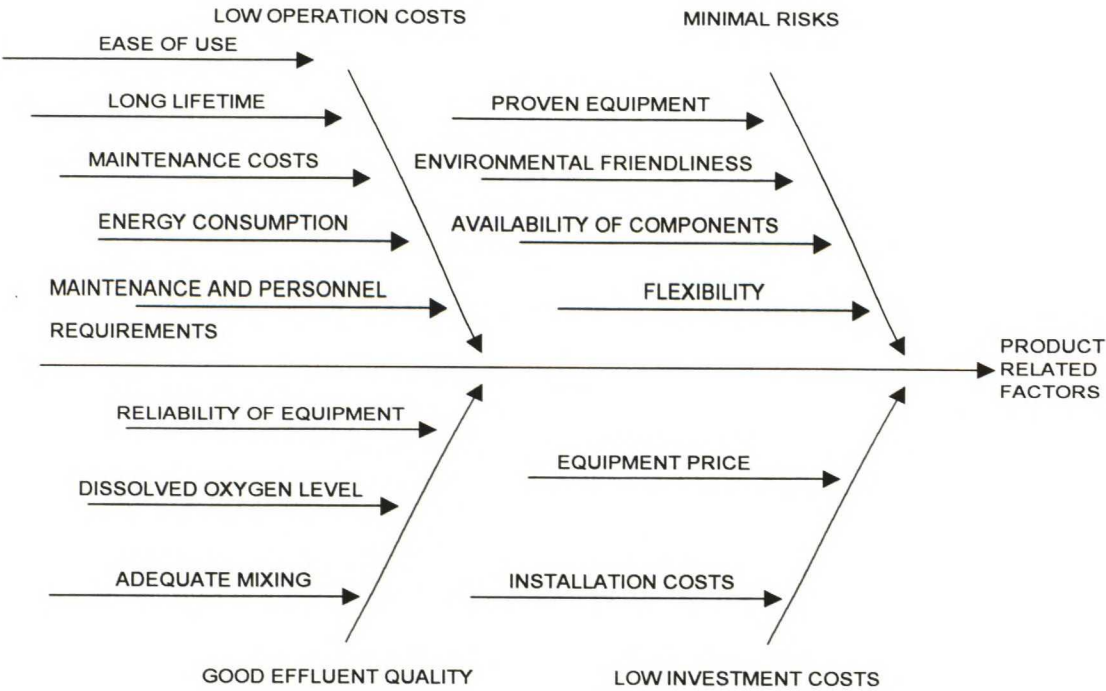


Figure 22. Factors related to the product

The relationship between the product related factors and the customers is described in Table 3. The relationship has been evaluated by the inquiries carried out for the Need Assessment Systems for Technological Applications project and for a project to study the waste water treatment market in China. Two persons representing research centres, five municipal experts, two industrial experts, two plant operators, six consultants, three contractors, and two Nopon distributors have given their opinion.

The persons were asked to evaluate the importance of various statements regarding aeration equipment selection. Number 4 means that the factor is very important and number 1 that it is not important at all.

Table 3. Relationship between the product related factors and the customers

NA not available

		Research Centres	Municipal Experts	Industrial Experts	Plant Operators	Consultants	Contractors	Distributors
Good effluent quality	Reliability of aeration equipment	4,0	3,8	4,0	3,0	3,1	3,0	4,0
	Dissolved oxygen level	4,0	4,0	4,0	4,0	3,8	NA	4,0
Low investment costs	Equipment price	4,0	3,7	3,5	3,6	3,1	3,7	3,7
	Installation costs	4,0	3,4	3,0	3,8	3,1	NA	3,5
Low operation costs	Energy consumption	NA	4,0	4,0	3,0	3,8	2,7	3,5
	Long lifetime	4,0	3,8	3,0	4,0	3,7	NA	4,0
	Maintenance costs	3,5	4,0	4,0	3,5	3,6	2,7	4,0
	Ease of use	4,0	4,0	4,0	NA	3,8	NA	4,0
	Maintenance and personnel requirements	3,3	3,8	4,0	4,0	2,8	2,3	2,8
Minimal risks	Flexibility	3,6	3,6	3,8	3,7	3,4	NA	3,3
	Environmental friendliness	4,0	3,2	2,0	2,5	2,4	NA	3,5
	Availability of components	4,0	3,8	3,0	3,5	3,7	NA	3,5
	Proven equipment	4,0	3,8	4,0	3,0	3,1	3,0	4,0

The table can be examined in two directions: one can analyse which factors are most important to a given customer, that is vertically, or one can observe to which customer a given factor is most important, that is horizontally.

Research centres seem to emphasise good effluent quality and other environmental factors. Investment costs are also important.

Municipal experts find low operation costs more important than low investment costs. They do not regard minimal risks as very essential. There is not much difference between the opinions of municipal and industrial experts. The slight differences are probably caused by the fact that the samples are quite small. It seems that municipal and industrial experts generally think in the same way.

Plant operators regard practical issues as the most important, as could be anticipated, since they are the only customers who use the aeration equipment continuously. Dissolved oxygen level, maintenance and

In regard to the consultants, it is difficult to determine the most important factors. Dissolved oxygen level, energy consumption, the lifetime of the equipment, ease of use, availability of components, and operation costs are important. It probably depends a lot on the consultant's ongoing projects which factors are the most important. Contractors find the investment costs very important.

Distributors find good effluent quality and the use of proven equipment very important. These are the selling arguments they use. Operation costs are more important for them than investment costs. The factors that are relevant to the distributors could be different if distributors of various aeration equipment had been interviewed. As it is, only the distributors of Nopol® aeration equipment have given their opinion.

Good effluent quality is essential to all the customers of the aeration equipment manufacturer, since this is the aim of waste water treatment. However, research centres, municipal and industrial experts, plant operators, and distributors emphasise this factor more than consultants and contractors do.

Customers wish to minimise capital costs, often without fully appreciating the working life of an installation and power consumption¹³⁰. This means that the price of the equipment is important. It has been observed that the choice of an aeration system depends mainly on the price, provided the performance corresponds to the needs of the customer¹³¹.

Many industrial customers, pulp mills for example, still regard waste water treatment as an extra cost. They want to buy a system which does not cost a lot, and which is maintenance-free. This, however, is slowly changing, at a

¹³⁰Pflüger, W. 1995. Choosing Wastewater Bubble Aerators. Water Management International, Pages 81 - 84.

¹³¹Anon. 1990. Assessment of Frings' Submersible Aerators in the United States and West Germany. Strategic Analysis - Europe, Brussels. Page 40.

different pace in different countries. The most advanced companies regard waste water treatment as an essential part of their production process.

A municipal council, when choosing aeration equipment, usually defines the investment costs and technical issues as crucial factors. Discounted year costs are usually not as important. This means that the selection of aeration equipment widely depends on the persons who present the project to the municipal council.

All the decision makers regard investment costs as a very important factor. Contractors think it is important because it affects the price of their complete offer to the investor. Investment costs are also important to the distributor: it is easier to sell inexpensive products than expensive ones. The price - quality relationship must of course be considered. Investment costs are important to the research centres, too.

Very often only the investment cost, that is the price of the aeration equipment, is considered. The investment cost is the most important factor to the municipalities, for example, who need to request money for every purchase separately. The industry is more concerned with the overall cost of the investment. However, this is changing now that the municipal waste water treatment plants are being privatised. The aim is usually to create units which can use their financial resources independently.

Due to the rules of many authorities, the cheapest bidder, and this means the aeration system with the cheapest initial costs, will get the job. It should not be like that. Compared to the total costs per year of a treatment plant, the capital costs for the mechanical equipment of the aeration basin amount to only 2 - 5 %. This means that even a tender for an aeration system that is 50 % more expensive than the cheapest one will result in a very small increase of the total costs per year. For this reason, the lowest initial costs of

the aeration system should not be the determining factor¹³². Even if the aeration equipment is not the biggest purchase when constructing a waste water treatment plant, it is usually considered thoroughly. The performance of the whole plant is highly dependent on the aeration. In addition, the operation costs of aeration amount to a large part of the operation costs of the plant¹³³.

Small operation costs are essential to most of the customers. Municipal and industrial experts value them the highest. Distributors think small operation costs are important because by making operation cost estimations they can sell their aeration system. Retrofits can also be justified by reductions in operation costs and by a short payback period.

Low operation costs are less important to the contractors. However, contractors find operation costs interesting when they are going to operate the plant on commission after construction. In this sample there were no contractors who are active in operating waste water treatment plants.

All the parties involved in selecting aeration equipment are concerned about the risks. Consultant, contractor, and distributor want to supply a system about which they can be sure there will not be any complaints later on. Research centres avoid risks related to the environmental friendliness of the equipment. Plant operators like to have equipment which operates without failure and which can be adapted to the changes in the treatment plant.

4.3 Service Related Factors

It is not clear whether the service related factors are important when choosing the aeration equipment manufacturer or whether the price and aeration performance are the only critical factors.

¹³²von der Emde, W. 1979. Criteria for Selecting Aeration Systems. Progress in Water Technology, volume 11, 3. Pages 201 - 203.

¹³³Medelberg, M. Marketing manager. Nopon Oy. Helsinki. 1996-04-23.

The service level of the manufacturer is partly something that the client can observe himself but it is partly also based on the image of the company.

The behaviour of the marketing personnel is an observable part of the service. The personnel should be professional and kind and reliable. The offer making and designing of the process should be accurate and quick. When the customer is disappointed with the product or service, the response is important.

When the client is choosing the aeration equipment manufacturer, he very often does not have experience of the service level of various manufacturers. Either he has not acquired aeration equipment earlier, or this was a long time ago. Then the decision is partly based on the image of the manufacturer, and on the stories heard from other clients. If the customer has purchased aeration equipment before, the past experience is certainly determinant.

Technical support is essential to most customers. Often the customers are not very familiar with aeration. Technical documentation, design programs, fast offer processing, process consulting know-how, complete offer, installation drawings and instructions, and knowledge of related equipment can be very important.

Delivery time and the terms of payment are also part of the service. Short delivery time, accurate deliveries, good export documentation, and contacts in the local language can be very important. Being able to help in finding financing for the project can be crucial in developing countries. However, most of the financing decisions have already been made when the aeration equipment manufacturer becomes involved in a project.

Equipment availability is often quite important. When the equipment delivery is critical to the construction schedule, the manufacturer which is known to be reliable is chosen. Long delivery times for spare parts and replacement units can also affect the decision. Training of the staff is usually important, too.

replacement units can also affect the decision. Training of the staff is usually important, too.

After sales service is significant when selling durable goods. Supervision of installation, guarantees on product and performance, and spare part deliveries are important. With continuous contacts, the customers feel they are cared for, and the company obtains feedback to serve its research and development work. Aeration equipment is a niche product, and it makes the aeration equipment market international. This is why a global service network is often needed.

The service related factors are presented in Figure 23.

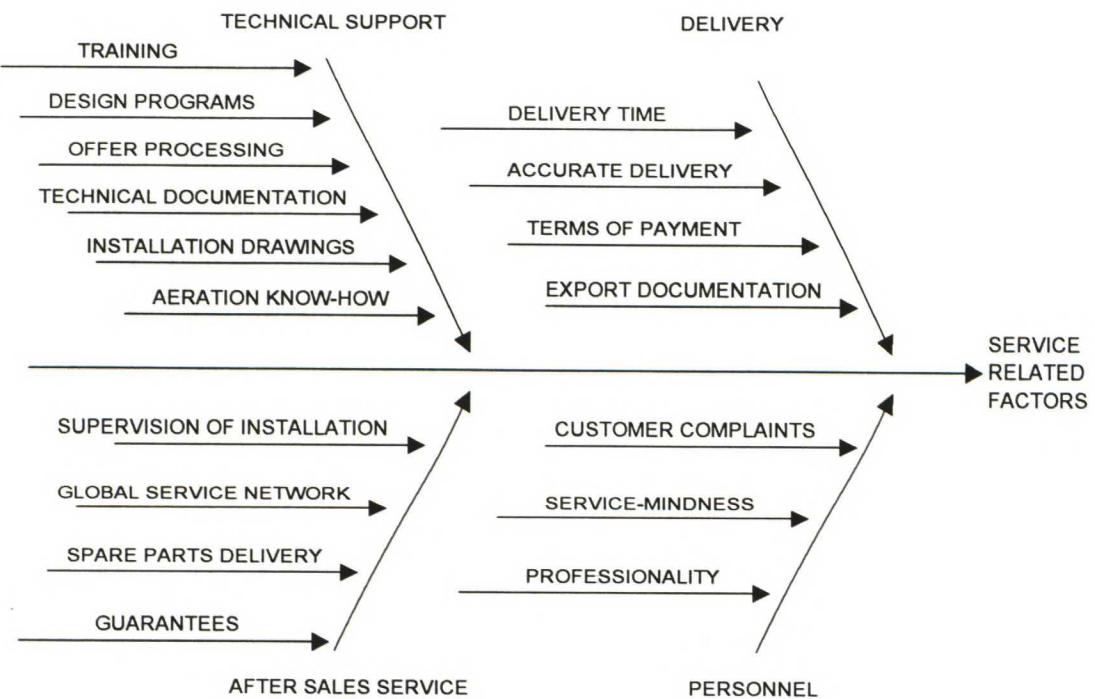


Figure 23. Factors related to the service

The relationship between some of the service related factors and the customers is described in Table 4.

Table 4. Relationship between the service related factors and the customers

		Research Centres	Municipal Experts	Industrial Experts	Plant Operators	Consultants	Contractors	Distributors
Technical support	Technical documentation	4,0	3,8	4,0	3,5	3,8	3,0	4,0
	Training	4,0	3,0	3,0	3,5	2,5	NA	3,0
Personnel	Professionality	4,0	3,8	4,0	3,5	3,8	NA	4,0
	Service-mindedness	4,0	3,7	3,7	3,4	3,4	NA	3,5
	Handling of customer complaints	4,0	3,9	4,0	3,5	3,1	NA	3,8
Delivery	Delivery time	4,0	3,4	2,0	3,5	2,7	NA	4,0
	Accuracy of delivery	4,0	3,8	3,7	4,0	3,8	2,3	NA
	Export documentation	4,0	3,0	3,0	2,0	2,7	NA	2,5
After sales service	Guarantee	4,0	3,7	3,7	4,0	3,8	2,3	3,8
	Spare parts	4,0	4,0	4,0	NA	3,4	NA	3,5

According to the table, all the service related factors are of high value to the research centres. This could be an error in the sense that perhaps the persons have thought that if they ever buy aeration equipment these would be important. Research centres buy aeration equipment only rarely for testing purposes. Technical documentation and the attitude of personnel can, however, be relevant.

Municipal and industrial experts have very similar opinions. They appreciate good technical documentation, service-minded and professional personnel, and an adequate after sales service.

Plant operators regard technical support, delivery and after sales service as significant. Accuracy of delivery, that is keeping to schedule and delivering the right products, and guarantees are particularly important.

Consultants mainly need technical support. Accuracy of delivery and guarantees are also of importance.

For the contractor, technical documentation is important in most projects. Many of the contractors mentioned separately the high value of complete offer documentation. Fast offer processing is also appreciated.

Distributors appreciate good technical documentation, professional staff, short delivery time, and guarantees. Guarantees are related to proven equipment which was analysed in the product related factors.

Technical documentation is important to most of the customers, primarily to research centres, experts, and distributors. The other component of technical support, training of the personnel operating the aeration equipment, is not very highly valued. This is rather surprising. However, all the customers appreciated ease of use. It could be concluded that the customers would like to have equipment which is so easy to use that no training is needed.

The personnel of the aeration equipment manufacturer is mostly important to the experts and to the research centres. Consultants and distributors consider it quite important.

Factors related to the delivery of the goods are relevant to all the customers. Short delivery time is not considered as important as on-time delivery.

Consultants and distributors appreciate the guarantees the most. After sales service is also important to plant operators and to the municipal and industrial experts.

4.4 Company Related Factors

Image, innovativeness, experience, aeration know-how and economic soundness are company related factors affecting the selection of aeration equipment. Activities and product ranges that support the marketing of aeration equipment belong to this group, too.

A good company image is formed by a long presence in the market, regular participation in international exhibitions, and the reputation of a solid international company. The products of the company should be known as reliable. The company should also be known as a reliable company which keeps its promises. Earlier experience of the company and of its products is important. The reference plants where the company has installed its

equipment are also important to the image. Product design is not the most important point, but it certainly does improve the company image. It can make the products look reliable and efficient.

The existence of a quality certificate is quite important, since the distributors, contractors, and consultants are trying to certificate their quality systems. However, studying the brochures of competitors reveals that not many aeration equipment manufacturers have a quality certificate.

Innovativeness consists of product development, continuous research and development, and test facilities. Co-operation with research centres gives an image of an innovative company. Innovativeness can also be a risk to the customer when the manufacturer sells new equipment which has not been tested thoroughly.

Experience of the company can be measured by the year of establishment, and by the length of time the aeration equipment has been in operation in reference plants. An international company can generally be considered as more experienced than a domestic company. However, a domestic company might have more experience in designing aeration systems for a local plant.

Aeration know-how constitutes the availability of various aeration systems, process knowledge, and the design of aeration systems. One way of estimating the aeration know-how of a company is the number of professional engineers it employs in sales, design, and engineering.

The economic status and financial stability of the company can be evaluated by considering the company turnover, the amount of staff, the share capital, and the ownership. Credit information reveals this. Something can be concluded from the terms of payment the company gives to its customers.

The product range of the aeration equipment manufacturer can be determinant in some cases, even if it is mainly not so important as the other factors. If the manufacturer has various types of diffusers and mechanical aerators, this equipment can be combined to achieve the best treatment

results. Sometimes the manufacturer also has supporting product ranges, like compressors, blowers, flow generators, or mixers. Then the manufacturer can make an offer package which is more favourable than if the goods were purchased separately. Marketing activities directed at the decision-makers by the aeration equipment manufacturer can be significant.

The company related factors are presented in Figure 24.

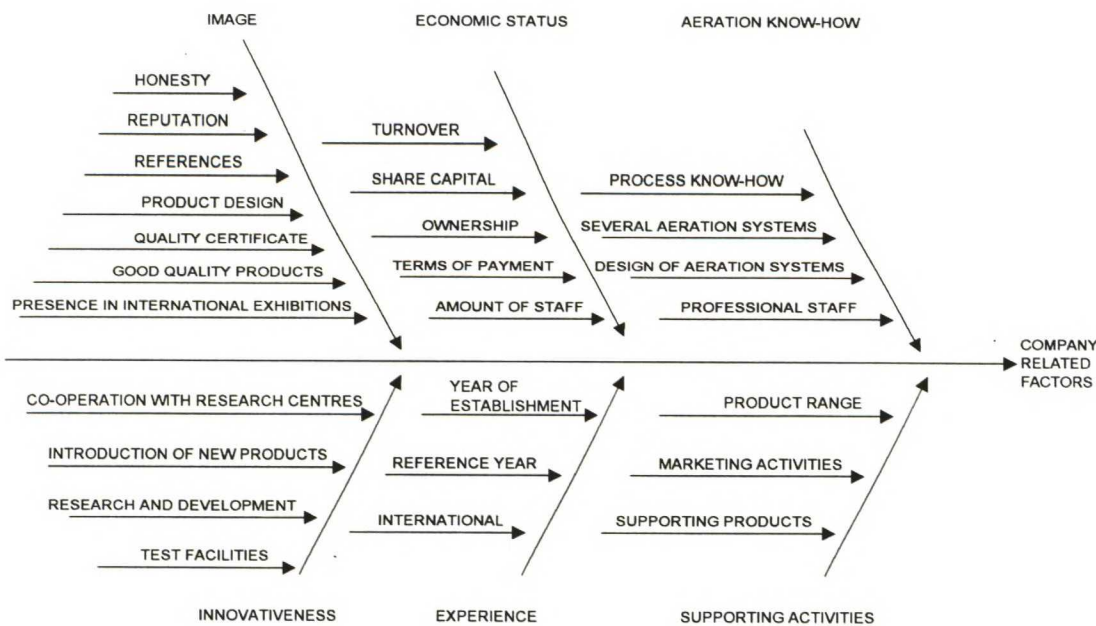


Figure 24. Factors related to the company

The relationship between the company related factors and the customers is described in Table 5.

Research centres appreciate innovativeness. This is not very surprising since they are of course interested in the advances in the waste water treatment field.

Municipal experts emphasise honesty and process knowledge. Industrial experts regard the availability of several aeration systems valuable as well. It enables them to deal with fewer suppliers.

Quality certificate and the reference list are important to the plant operators.

Table 5. Relationship between the company related factors and the customers

		Research Centres	Municipal Experts	Industrial Experts	Plant Operators	Consultants	Contractors	Distributors
Image	Quality certificate	NA	3,0	3,0	4,0	3,2	NA	3,0
	Good quality products	2,0	3,8	3,0	2,5	2,7	3,0	3,0
	Honesty	4,0	3,9	3,5	3,5	3,6	NA	4,0
	References	4,0	3,8	3,0	4,0	3,7	2,7	3,5
Innovativeness	Research and development	4,0	3,0	2,5	4,0	2,7	2,3	3,0
	Introduction of new products	4,0	3,8	NA	3,0	2,7	NA	3,5
Aeration know-how	Process know-how	2,0	4,0	4,0	NA	3,8	NA	4,0
Product range	Availability of several aeration systems	4,0	3,6	4,0	3,0	2,8	NA	3,5

Consultants find honesty, references, and process knowledge the most important company related factors. Contractors emphasise the quality of the products. Innovativeness is not very important to consultants and contractors.

Honesty and process knowledge are important to distributors. Distributors have a very close relationship with the aeration equipment manufacturer, and openness and honesty are of course necessary. Distributors often need assistance in designing aeration systems, too.

Company image is rather important to all the customers. A quality certificate is not as important as one might think. The good quality of products is not emphasised either. Honesty and references are more important. Probably the earlier experience of the company is the most important factor related to the image, but it is very difficult to measure.

Innovativeness is not valued very highly. Research centres value it the most, and contractors the least. Extra features and research and development work raise the price. Nopol[®] diffusers have wedge piece attachment and a check valve, which are nice to have but the customers are often not willing to pay for them when comparing prices with those of the competition. However, the distributor benefits from the innovativeness, since the distributor can

introduce new products to the market and attract the interest of the customers.

Aeration know-how is relevant to all the customers. Aeration is a complex process, and professional assistance is often needed.

Distributors, contractors, and consultants appreciate the assistance and marketing activities of the equipment manufacturer from the standpoint of the end user. Product range is interesting to the distributors.

4.5 Trends in Waste Water Treatment

At the moment, there are various trends prevailing in the field of waste water treatment. New trends set new requirements for aeration equipment. The trends are usually transferred from one customer to another since this is a chain reaction. A research centre may discover a new form of pollution. After a time a regulation applies to this which regulates the operation of waste water treatment plants. The management of the treatment plant asks a consultant to solve the problem. The aeration equipment manufacturer is usually given the requirement by the consultant or contractor.

The trends have been identified through discussions within Nopon Oy and with various experts in this field. It is difficult to give a source of information for a trend since it represents a summary of the views of many people. Here, the trends have been classified into trends derived from environmental issues, from costs, and from the market becoming more international. A trend has been divided into components according to the customers of the aeration equipment manufacturer.

4.5.1 Environmental Issues

Environmental issues that affect the waste water treatment sector can derive from research centres and from public opinion. Chemicalisation of the environment, injurious effects of aerosols, heavy metals in waste water treatment sludge, and the harmful effects of nutrients on watercourses are

research results from various research centres. These have led to strict emission restrictions.

Today, man uses more and more chemicals. Municipal sewage contains a wide spectrum of pollutants, such as heavy metals, and pathogens. These have negligible biological oxygen demand, and this should not be the only qualifier for effluent quality. Conventional treatment methods do not remove these pollutants, and new treatment methods are being developed. It seems that membrane technology, adsorption, ozonisation, oxidation, and slow sand filters could solve this problem. These methods do not require aeration, but it seems that these methods would not be used alone. The activated sludge process with aeration would most probably precede these more advanced methods¹³⁴.

Aerosols are injurious to health. The authorities have imposed regulations on the working environment, and there is a clear need to minimise air emissions from aeration basins. Pathogens can infect the people working in the treatment plant, but they can also affect the inhabitants living nearby. Consequently, surface aerators which produce a lot of aerosols are no longer recommended in many countries. This has also led to the covering of aeration basins¹³⁵.

There are heavy metals in the sludge produced by waste water treatment. Thus, it is not recommended that the sludge is used in agriculture. Sludge disposal is expensive, and it would be better to produce less sludge. This can be achieved by developing new processes, such as anaerobic processes¹³⁶.

¹³⁴Ruokonen, M. 1996. Aeration Equipment in Biological Waste Water Treatment. Helsinki University of Technology, Faculty of Forest Products Technology, Laboratory of Environmental Protection Technology, Special Study. Page 78.

¹³⁵Ruokonen, M. 1996. Aeration Equipment in Biological Waste Water Treatment. Helsinki University of Technology, Faculty of Forest Products Technology, Laboratory of Environmental Protection Technology, Special Study. Page 79.

¹³⁶Ruokonen, M. 1996. Aeration Equipment in Biological Waste Water Treatment. Helsinki University of Technology, Faculty of Forest Products Technology, Laboratory of Environmental Protection Technology, Special Study. Page 81.

Nitrogen and phosphorus are growth-limiting nutrients which should be removed from the waste water. Phosphorus has traditionally been removed by precipitation. The chemicals needed for this are expensive, and in some countries they are not readily available. Phosphorus removal produces more sludge, too. This is why biological phosphorus removal processes have been developed. The removal of nitrogen is a recent development. It can be removed biologically by nitrification and denitrification. This requires the aeration equipment to be capable of being used intermittently, that is, aeration can be shut off for a while when only mixing occurs. Directive 271 of the European Union makes nutrient removal obligatory for plants that dispose the water into sensitive water courses by 1998. This means a lot of revamping in old plants¹³⁷.

The strict emission restrictions have led to a situation where it is not possible to interrupt the treatment process for reparation and maintenance, and discharge untreated waste water to the receiving water body. Operational reliability, and in situ cleaning are of increasing importance. Lifiable aeration equipment is also becoming more popular. One way of avoiding interruption is to build parallel lines, so that one at a time can be shut down for reparation. This is a normal practice in municipal waste water treatment plants, and it is coming to industrial applications, too¹³⁸.

Public opinion on environmental issues has mostly affected industrial waste water treatment. It has prompted many industrial companies to take action on waste water treatment voluntarily. This has led to the construction of new waste water treatment plants and to the development of closed and semi-

¹³⁷Ruokonen, M. 1996. Aeration Equipment in Biological Waste Water Treatment. Helsinki University of Technology, Faculty of Forest Products Technology, Laboratory of Environmental Protection Technology, Special Study. Pages 78 - 79.

¹³⁸Ruokonen, M. 1996. Aeration Equipment in Biological Waste Water Treatment. Helsinki University of Technology, Faculty of Forest Products Technology, Laboratory of Environmental Protection Technology, Special Study. Page 78.

closed water cycles. Semi-closed water cycles produce more concentrated waste waters which may require new treatment methods¹³⁹.

Now that in many of the European countries the waste water treatment is handled adequately in big cities, there is pressure to minimise non-point source pollution from agriculture, for example. This also means that better care will be taken of the smaller cities and villages, and many new waste water treatment plants will be built for small cities¹⁴⁰.

The trends regarding environmental issues are explained in Figure 25.

4.5.2 Costs

There is always a need to reduce costs. One way of reducing costs in municipal waste water treatment is to privatise the water supply and waste water treatment services. This is happening in many European countries but also outside Europe, as in South America. In many developing countries the municipalities would never have enough financial resources to construct water supply and waste water treatment facilities, and privatisation is the only possibility. Private ownership seems to make the operation more efficient. In developing countries, the construction of waste water treatment plants is often made in the form of a Build, Own, Operate, and Transfer contract. After a given time, often 25 years, the plant will revert to the local authority¹⁴¹.

¹³⁹Ruokonen, M. 1996. Aeration Equipment in Biological Waste Water Treatment. Helsinki University of Technology, Faculty of Forest Products Technology, Laboratory of Environmental Protection Technology, Special Study. Page 80.

¹⁴⁰Ruokonen, M. 1996. Aeration Equipment in Biological Waste Water Treatment. Helsinki University of Technology, Faculty of Forest Products Technology, Laboratory of Environmental Protection Technology, Special Study. Page 80.

¹⁴¹Chesnot, C. 1996. Les européens à la recherche d'un second souffle à l'export. Hydroplus, April 1996, No 62 special issue. Pages 16 - 19.

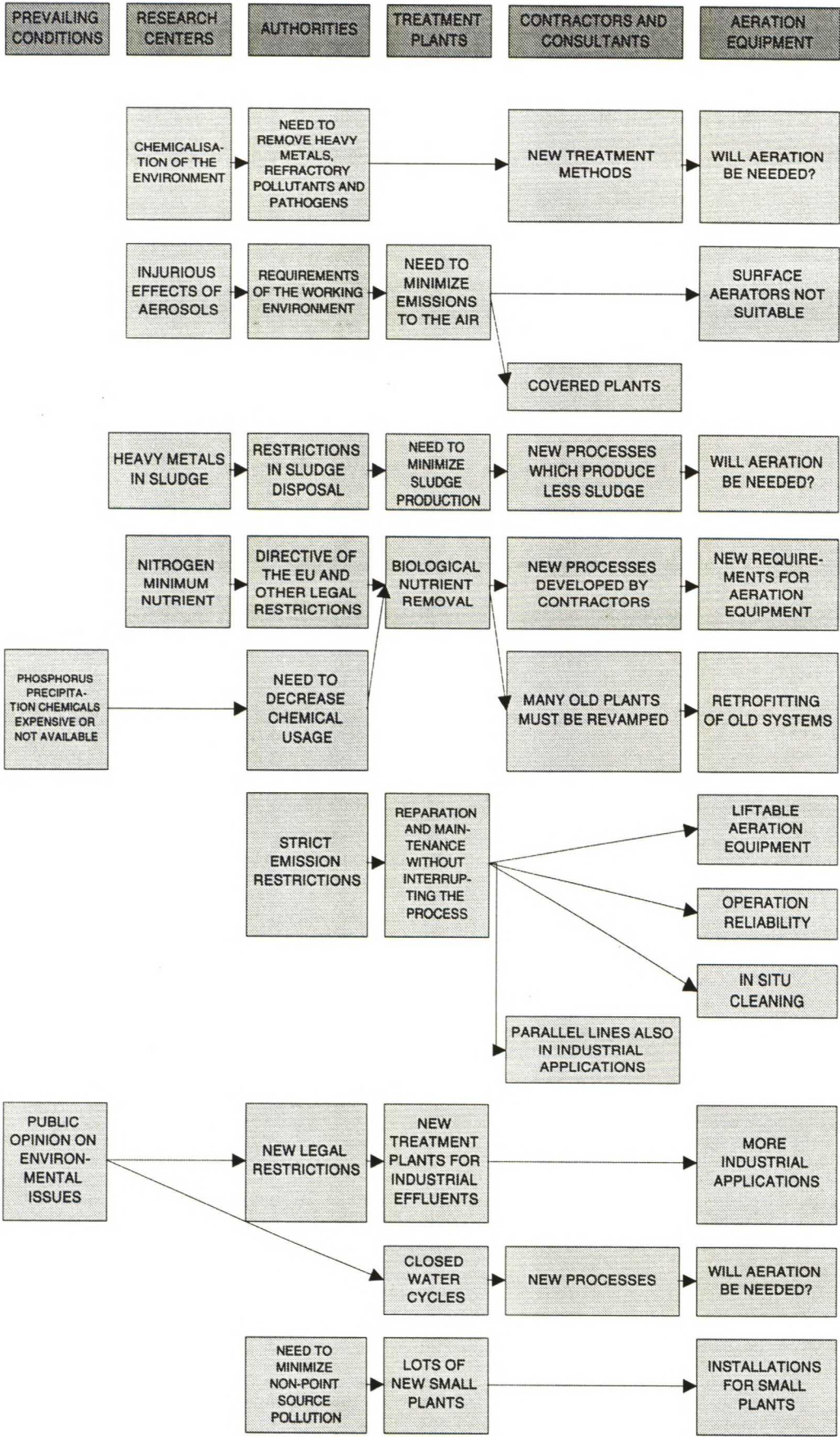


Figure 25. Trends deriving from environmental issues

In most of the big cities the land is scarce and expensive. From this it follows that it has become difficult to expand old waste water treatment plants that are often surrounded by inhabited areas. One solution to the problem is to make the aeration basins deeper. This improves the aeration efficiency, too. Traditionally, a common depth has been 3 - 4 m for an aeration basin¹⁴². The trend for deeper basins began in the 1970s. Now plants are being operated at depths of over 10 m, with 6 - 8 m being normal. A deeper basin places new requirements on the aeration equipment. Usually the self-aspirating aerators and surface aerators are not efficient enough for deep basins. Only the aeration equipment with compressed air is feasible. When the air has to be supplied deeper, it becomes hotter. This places restrictions on materials¹⁴³.

The building of new waste water treatment plants presents the same problem with scarce and expensive land. The treatment plants have to be located near the place where effluents are produced. The solution can be deeper basins which take less space, but there are also other alternatives like covering the plant, building multi-storey treatment plants, and applying new processes that are more compact. In Helsinki, the new Viikinmäki central waste water treatment plant has been covered to avoid disturbing the inhabitants living nearby. In Japan, it is common to build multi-storey treatment plants. New compact waste water treatment processes are also becoming widely used. For example, the sequencing batch reactors take up less space than the normal activated sludge process.

Energy is expensive, and production of energy is also harmful to the environment. This has led to the development of processes that consume less energy, such as the root zone method and the anaerobic methods. The common activated sludge method uses a lot of energy, and most of the

¹⁴²Anon. 1988. Aeration. Manual of Practice FD - 13. Water Pollution Control Federation. Page 93.

¹⁴³Ruokonen, M. 1996. Aeration Equipment in Biological Waste Water Treatment. Helsinki University of Technology, Faculty of Forest Products Technology, Laboratory of Environmental Protection Technology, Special Study. Pages 76 - 77.

energy is used for aeration. Aeration equipment which requires less energy is becoming more popular¹⁴⁴.

Labour is expensive, too. In many plants, the labour force has been reduced to a minimum. At the same time, control and automation technology has developed, and many of the tasks that people did earlier can nowadays be done by machines. The staff still left has less time for maintenance and reparation. Biological nutrient removal processes and sequencing batch reactors require advanced automation technology¹⁴⁵.

The employees at the waste water treatment plants are nowadays more qualified than previously. The profession is more respected, too. This, together with the automation technology, has made it possible to introduce more complicated processes. The employees are also more interested in developing the processes themselves. Versatility in aeration equipment is highly valued¹⁴⁶.

Costs can be reduced by building large central plants instead of many smaller ones. Large plants benefit from the economics of scale, and they are often more efficient as well¹⁴⁷.

In regard to the processes, there seems to be a trend to combine attached growth biological methods with aeration. Attached growth methods are ones where the biomass is attached to solid media such as rock or specially designed plastic materials. In suspended growth methods, like the activated

¹⁴⁴Ruokonen, M. 1996. Aeration Equipment in Biological Waste Water Treatment. Helsinki University of Technology, Faculty of Forest Products Technology, Laboratory of Environmental Protection Technology, Special Study. Page 79.

¹⁴⁵Ruokonen, M. 1996. Aeration Equipment in Biological Waste Water Treatment. Helsinki University of Technology, Faculty of Forest Products Technology, Laboratory of Environmental Protection Technology, Special Study. Page 79.

¹⁴⁶Ruokonen, M. 1996. Aeration Equipment in Biological Waste Water Treatment. Helsinki University of Technology, Faculty of Forest Products Technology, Laboratory of Environmental Protection Technology, Special Study. Page 79.

¹⁴⁷Ruokonen, M. 1996. Aeration Equipment in Biological Waste Water Treatment. Helsinki University of Technology, Faculty of Forest Products Technology, Laboratory of Environmental Protection Technology, Special Study. Page 80.

sludge method, the biomass is freely suspending in the water. At the 11. International Trade Fair for Waste Water and Waste Disposal in München in 1996, one could see several installations where attached growth methods, such as rotating biological contactors had been combined with aeration. Traditionally, attached growth methods have received the required air in ways other than by aeration. One application had a normal aeration basin which was filled with hanging strings. Underneath there were disc diffusers.

Regarding the sewer systems, there is a trend to balance water flows. One objective is to avoid rain water entering the sewer system. This will affect the design of waste water treatment systems, since the difference between the average daily flow and peak flow will become smaller¹⁴⁸.

The trends deriving from reducing costs are shown in Figure 26.

4.5.3 Global Market

Aeration equipment is a typical niche product for which the market is very small in most of the countries but globally there is enough demand. Most of the aeration equipment manufacturers are active internationally.

The waste water treatment market is becoming increasingly international. Tenders are international. The directives of the European Union stipulate that the tenders for municipal projects have to be open to all the companies in the member countries.

Consultant and contracting companies are also increasingly international. They are often developing their own processes in order to differentiate themselves from their competitors¹⁴⁹.

¹⁴⁸Ruokonen, M. 1996. Aeration Equipment in Biological Waste Water Treatment. Helsinki University of Technology, Faculty of Forest Products Technology, Laboratory of Environmental Protection Technology, Special Study. Page 80.

¹⁴⁹Ruokonen, M. 1996. Aeration Equipment in Biological Waste Water Treatment. Helsinki University of Technology, Faculty of Forest Products Technology, Laboratory of Environmental Protection Technology, Special Study. Pages 80 - 81.

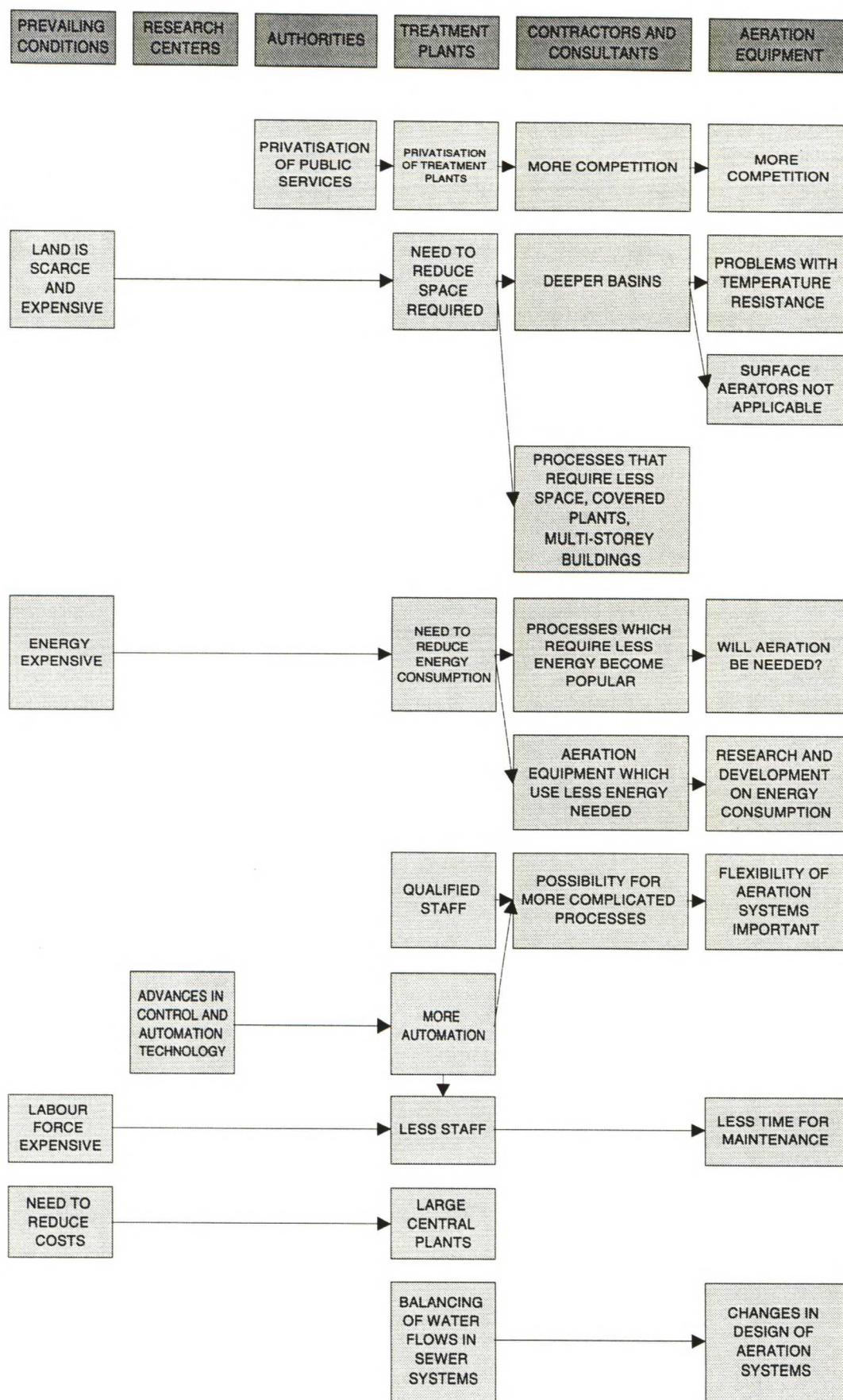


Figure 26. Trends deriving from reducing costs

Environmental problems in developing countries are rather urgent. For solving them, international co-operation is needed. Financial aid usually comes from the developed countries. Many waste water treatment plants will be built in Eastern Europe, Asia, and South America in the next few years. These projects will produce new export opportunities for aeration equipment manufacturers. Two kinds of installations are needed. On one hand, the developing countries require new reliable technology. On the other hand, in some countries, there is a need for economical solutions which do not require qualified staff and which energy consumption is low¹⁵⁰.

The trends deriving from the market getting more international are shown in Figure 27.

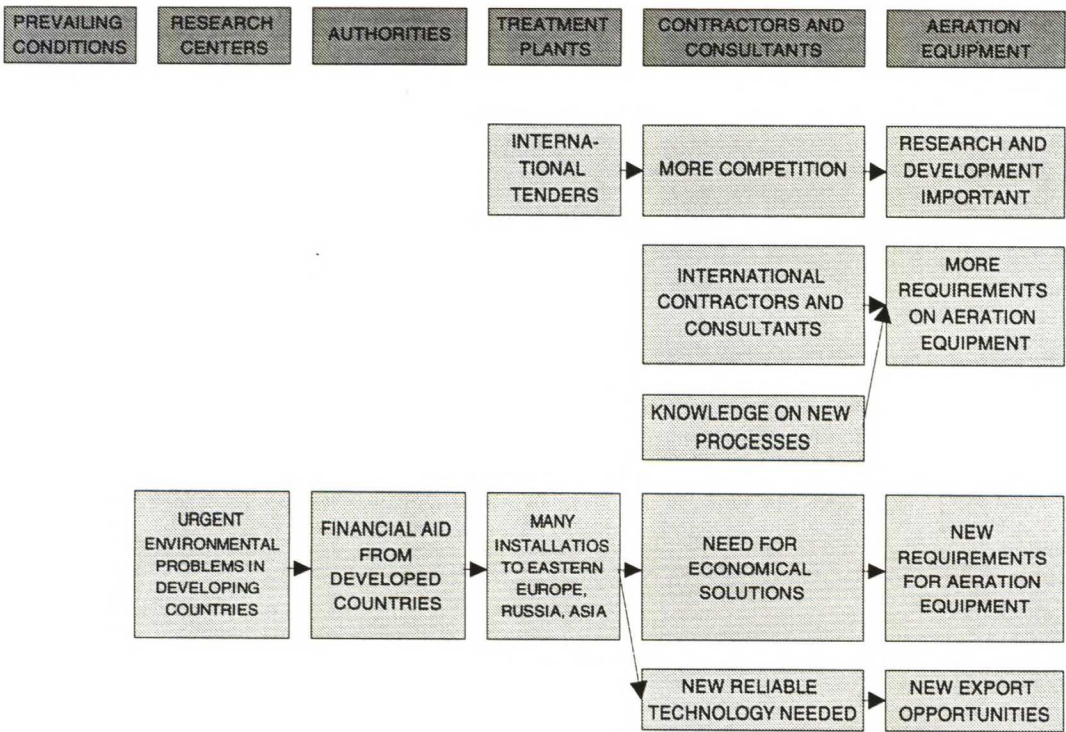


Figure 27. Trends deriving from the market becoming more international

¹⁵⁰Ruokonen, M. 1996. Aeration Equipment in Biological Waste Water Treatment. Helsinki University of Technology, Faculty of Forest Products Technology, Laboratory of Environmental Protection Technology, Special Study. Page 81.

4.6 Local Factors

Local factors can be divided into two: to factors arising from the company, that is, how it is present in a given market, and to factors arising from the country, that is, how the local aeration market is.

4.6.1 Company Representation

An aeration equipment manufacturer can be represented in a given country either by a distributor, that is a company that has made a distribution contract with the manufacturer, by an agent, or directly by a subsidiary of the manufacturing company. It is of course also possible for the manufacturer not to have any representative in a country. Since Nopon Oy uses the distributor strategy, it is treated in more depth here. Nopon Oy has appointed distributors in 29 countries. Along with Finland, it has its employees working in Thailand, Italy, and the United States. The countries where Nopon Oy does not have any representative at all are handled directly from Finland.

Probably it is quite important to the customer that the company has a local representative. The time during which a person has been representing the company is relevant, too. It is important that the distributor and the company are respected. Good contacts with local decision makers are essential. Many sales have been lost when the competitor has had better contacts.

The distributor should have good technical knowledge on aeration, and he should be able to understand customer's problems. This gives the distributor competence to make technical offers without help from the aeration equipment manufacturer. In this way offer processing will be quicker. The distributor should also be able to make local binding commercial offers. Customers often need help in installing the aeration equipment, and sometimes supervision of installation is also necessary. These tasks can also be handled by a competent distributor without the help of the manufacturer.

If the distributor has spare part storage, it is certainly an advantage to the customer. Local assembly and production of aeration equipment can also be taken as an advantage. If the local distributor represents supporting products, the distributor can form a package of related products, like pumps and mixers, for the customer. The customer will also most probably appreciate documents, like brochures and manuals, in the local language.

4.6.2 Local Situation

In the environmental engineering market, there are four central elements that regulate business opportunities. These are legislation, execution of laws, mechanisms to finance the investments needed, and the local market.

The local regulations and laws affect the demand for aeration equipment. Even if the environmental laws are basically the same in all the countries of the European Union, the execution of the laws varies.

The local market can be divided into the decision making process, climate and geography, competition, trends, consultants and contractors, price of energy and labour, and existing municipal and industrial waste water treatment plants.

The decision making process differs from country to country. It is also different for municipal and industrial projects. It is very important to identify the real decision makers. If the local decision making process is unknown, big mistakes can be made.

The situation in waste water treatment is also different in every country. In some countries, there are almost no waste water treatment plants, and in some countries there are only revampings and extensions of the plants to be carried out. Local industry affects the need for waste water treatment, too.

The local climatic conditions are important as well. In cold countries, surface aerators are not recommended because of freezing problems, for example.

The local aeration market affects the choice of equipment, of course. The presence of international and local competitors in the market affects the situation. Competition can sometimes make the marketing easier. If, for example, disc diffusers are very common in a given country, it will be quite easy to introduce a new brand to the market. If disc diffusers are not common, one has to give assurance that this kind of aeration method is suitable. Competition can also work the other way. It has happened that a competitor has ruined the market of a given type of aeration equipment by using a country as a test market. It has introduced a product that was not good. Subsequently, it takes a great deal of effort to assure people that this aeration method can function well.

If there is a dominant local consultant or contractor that favours a given aeration equipment manufacturer, it can be very difficult to enter the market. There may be specifications for certain kinds of aeration equipment already included in the tenders.

The local price of energy and labour considerably affect the selection. If energy is very expensive, an aeration system is selected which consumes little energy. If energy supply is not always secured, there are limitations to aeration equipment selection. Some aeration equipment cannot handle power failures.

A global after sales service is appreciated by international consultants and contractors.

Local trends are also important. Global trends can arrive late in some countries, and some countries are the creators of these trends.

The factors related to the local situation are presented in Figure 28.

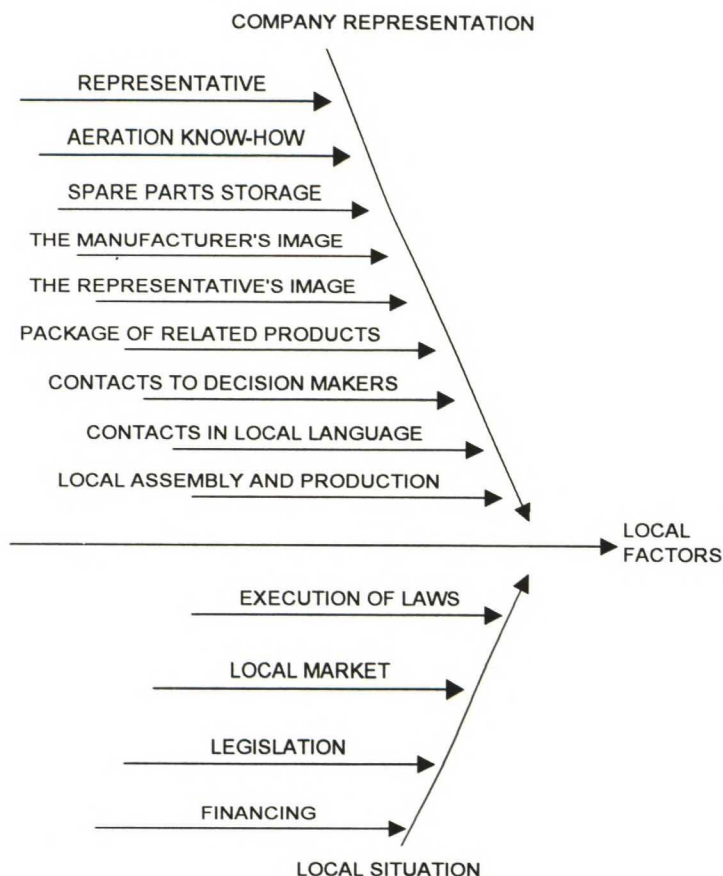


Figure 28. The factors related to the local situation

The local market is analysed below in three case countries.

4.6.2.1 Finland

Finland has been chosen as an example, since it is the home market of Nopon Oy, and since Finland is very advanced in waste water treatment. It is a mature market where no big growth can be achieved.

After Finland joined the European Union in 1995, France and Italy in theory have the same laws on waste water treatment as Finland. However, the situation is different in all the three countries. Application of the laws has been and is punctual in Finland.

Directive 271 of the European Union makes nutrient removal obligatory in sensitive areas. Sensitive areas are areas with a threat of eutrophication. Most of the coast and lakes in Finland have been classified as sensitive. The concentration limit is 15 mg/l for plants with population equivalent 10 000 -

100.000, and 10 mg/l for plants with population equivalent > 100 000. The minimum percentage of nitrogen reduction is 70 - 80 %.

The overall situation in waste water treatment in Finland is good. As long ago as the 1910s, the construction of treatment plants started¹⁵¹. One of the major trends prevailing in Finland is revamping of existing waste water treatment plants, since most of the plants have been constructed in the 1970s. Revamping is mainly caused by the adoption of Directive 271.

The major processes in use are modifications of the activated sludge process. Aerated lagoons are still in use in some pulp and paper mills. Biological nutrient removal is becoming important.

There are around 550 waste water treatment plants in Finland. They treat the waste waters of almost 4 million inhabitants. Treatment is biological - chemical in 86 % of the plants¹⁵². Nopon Oy has supplied its aeration equipment to around 200 Finnish waste water treatment plants¹⁵³. The municipal waste water treatment plants are managed by municipalities or consortia of municipalities. The waste water treatment plants are increasingly independent of the municipality. There is a trend to convert waste water treatment works into commercial enterprises. These units finance the operation and investments by cash flow financing. They often pay a certain percentage of their turnover to the municipality as return to the investment. No private company will be able to buy the business, however.

The treatment of industrial effluents was begun later than that of municipal sewage, but nowadays all major industrial plants have adequate waste water treatment.

¹⁵¹Lehtonen, J. 1994. Jäteveden puhdistuksen kehitys Suomessa pitkällä aikavälillä. Tampere, Tampere University of Technology, Institute of Water and Environmental Engineering. Page 4.

¹⁵²Anon. 1995. Vesihuoltolaitokset 1993. Vesi- ja ympäristöhallinnon julkaisuja, sarja A, 192. Vesi- ja ympäristöhallitus, Painatuskeskus, Helsinki. Page 11.

¹⁵³Reference database of Nopon Oy.

A characteristic of the Finnish waste water treatment sector is the multitude of waste water treatment plants in pulp and paper mills. Waste water emissions from the pulp and paper industry have decreased drastically during the last two decades. The dominance of the pulp and paper industry can be seen in the fact that special aeration equipment for treating its effluents has been developed. The Nopol[®] submerged aerator mixer is one example. Nowadays this is commonly used to treat municipal sewage as well.

In Finland, the plant operators in the municipal plants are highly qualified. Being a plant operator is nowadays a respected profession. When the Viikinmäki plant was constructed, the plant operators could influence the selection of equipment. The situation is not as good in industrial plants, where the persons who are not capable of doing anything else often take care of the waste water treatment plant. This situation is changing, however.

Competition in the aeration equipment industry is quite stiff in Finland. All the major international players are present in the country. However, Nopon Oy has a home market advantage. In Finland, it is a well known brand in the waste water treatment field.

In regard to geography, Finland is a sparsely populated country. This means that most of the waste water treatment plants are small. However, there is a trend to build larger central plants. For example, in Helsinki, there used to be six treatment plants but now there is only the Viikinmäki plant treating all the waste water from Helsinki and from some of the surrounding municipalities.

The cold climate sets requirements for the waste water treatment processes and aeration equipment. Nitrification has been difficult to achieve in this climate. Surface aerators are not very suitable because of the freezing problems.

4.6.2.2 France

France is divided into six hydrological basins¹⁵⁴: Artoise - Picardie, Seine - Normandie, Rhine - Meuse, Loire - Bretagne, Adore - Garonne, and Rhône - Méditerranée - Corse. Every hydrological basin has a basin agency, Agence du Bassin or Agence de l'Eau. The agencies give technical and financial support to public and private projects. The financial aid can be up to 40 % of the total costs of a project¹⁵⁵. The agencies also take care of controlling water quality, classification, and statistics¹⁵⁶. In France, it seems that the concept of hydrological basins is successful.

The municipalities are very small in France. There are approximately 37 000 municipalities, of which 31 000 municipalities have less than 2 000 inhabitants. This explains why there are many consortia of municipalities. Two-thirds of the municipalities have unified their strengths in water and waste water treatment. Altogether, there are 13 500 units taking care of the water supply^{157,158}.

There are around 10 000 municipal waste water treatment plants in France. However, many cities still lack such plants, and only 55 % of the waste water

¹⁵⁴a hydrological basin is an area from which the rain water and the water from melting snow and glaciers gather into a given watercourse

¹⁵⁵Rautanen, S-L. 1995. Vesihuollon nykytila Suomessa ja viidessätoista muussa Euroopan maassa. Vesitalous, volume 36, 6. Pages 1 - 7.

¹⁵⁶Carlson, S. 1990. Ympäristötekniikan tilanne Ranskassa. TEKES, Teollisuussihteeriraportti 5 / 1990. Valtion painatuskeskus, Helsinki. Page 13.

¹⁵⁷Morange, H. 1993. Vesihuoltopalveluiden järjestelyt Ranskassa - toteuttamiskelpoisia ideoita Suomessa? Vesitalous, volume 34, 4. Pages 12 - 16.

¹⁵⁸Bustarret, J. 1992. Management of French Water Supply and Sewerage Systems. In: Saarikoski, K (editor). Finnish - French Symposium on Water Supply and Sewerage. VTT Symposium 129. Technical Research Centre of Finland (VTT), Painatuskeskus, Helsinki. Pages 26 - 31.

is treated ¹⁵⁹. Nopon Oy has supplied its aeration equipment to around 40 French waste water treatment plants¹⁶⁰.

Paris has three waste water treatment plants: Seine Aval, Seine Amont, and Marne Aval. These do not have enough capacity to treat all the waste water, and three plants more will be built in the near future: Les Grésillons, Seine Centre, and La Morée. The older plants need revamping, too¹⁶¹.

Performance has improved in industrial waste water treatment. The emissions decreased by 50 % during the 1980s¹⁶².

In France, the organisation and production of water supply and sewerage services are clearly separated¹⁶³. The municipalities are responsible for organising the water supply and sewerage services. Several municipalities may also group together into a "Syndicat de communes", Waste Water Authority, for this task. The municipalities are responsible for controlling water supply and sewerage services. The production of these services can be entrusted to private companies or the municipalities can take care of this.

Privatisation is one of the identified trends prevailing in the waste water treatment sector¹⁶⁴. Privatisation is becoming common in France. Generally, privatisation of waste water treatment plants increases competition since the companies that run several waste water treatment plants are more professional and cost-conscious. Water supply in France has been privatised

¹⁵⁹Carlson, S. 1990. Ympäristötekniikan tilanne Ranskassa. TEKES, Teollisuussihteeriraportti 5 / 1990. Valtion painatuskeskus, Helsinki. Page 12.

¹⁶⁰Reference database of Nopon Oy.

¹⁶¹Hayward, K. 1996. Capital Investment. Water Quality International, March / April 1996. Pages 22 - 25.

¹⁶²Carlson, S. 1990. Ympäristötekniikan tilanne Ranskassa. TEKES, Teollisuussihteeriraportti 5 / 1990. Valtion painatuskeskus, Helsinki. Page 12.

¹⁶³Rautanen, S-L. 1995. Vesihuollon nykytila Suomessa ja viidessätoista muussa Euroopan maassa. Vesitalous, volume 36, 6. Pages 1 - 7.

¹⁶⁴Ruokonen, M. 1996. Aeration Equipment in Biological Waste Water Treatment. Helsinki University of Technology, Faculty of Forest Products Technology, Laboratory of Environmental Protection Technology, Special Study. Page 78.

since the end of the 19th century¹⁶⁵. At the end of the 1980s, private companies took care of 55 % of the water supply. Waste water treatment is also being privatised, 30 - 40 % of it was privatised at the end of the 1980s¹⁶⁶.

The municipality itself can manage the water supply and sewerage services, a system known as direct management, or it may contract operation out to a private water company, a system known as "gestion déléguée" or delegated management¹⁶⁷. There are several ways of making a contract with a private company. The municipalities have the right to decide the price of the services, even if there is a private company producing them. This means that private companies compete on technical know-how and organising skills. Even if there are many companies active in this field, it has been claimed that there is no real competition since the big companies have divided up the market. It is more a case of competition between the municipality, which can take care of organising the services, and a private company carrying them out¹⁶⁸.

Delegated management can be divided into concession contracts and leasehold contracts. Concession contracts developed first, during the second half of the 19th century. Concession is a contract on the basis of which the private company undertakes all the investments and revamping. After termination of the contract, the company gives the equipment to the municipality. The company produces the services and takes all the risks. However, the municipal council decides the price of the service. The company must manage and operate the service for the duration of the concession and hand

¹⁶⁵Juhola, P. 1995. Vesihuoltolaitos yhdyskuntien palveluorganisaationa. Vesitalous, volume 36, 6. Pages 9 - 14.

¹⁶⁶Carlson, S. 1990. Ympäristötekniikan tilanne Ranskassa. TEKES, Teollisuussihteeriraportti 5 / 1990. Valtion painatuskeskus, Helsinki. Page 12.

¹⁶⁷Bustarret, J. 1992. Management of French Water Supply and Sewerage Systems. In: Saarikoski, K (editor). Finnish - French Symposium on Water Supply and Sewerage. VTT Symposium 129. Technical Research Centre of Finland (VTT), Painatuskeskus, Helsinki. Pages 26 - 31.

¹⁶⁸Morange, H. 1993. Vesihuoltopalveluiden järjestelyt Ranskassa - toteuttamiskelpoisia ideoita Suomessa? Vesitalous, volume 34, 4. Pages 12 - 16.

it over in good working order upon termination of the contract to the municipality involved, which then takes up ownership of the service. In return, the private company is remunerated from the sale of water at a price stipulated in the contract. The duration of concession contracts is long, being a minimum of 25 years, to ensure the private company the repayment of funded capital. The company's results will depend on its ability to manage the service with a minimum of outlay while keeping its contractual obligations under the control of the municipality¹⁶⁹.

Lease-hold contracts, so called "affermage" contracts are more frequent than concession contracts. Leasing often follows a concession contract. Under the terms of lease-holding, the municipality retains ownership of the water service facilities it had created itself or received upon termination of a concession contract. It delegates no more than the operation of its service to the private water company through a lease-hold contract. The contract specifications stipulate all the company's obligations regarding operation of the service and maintenance of the facilities with oversight exercised by the municipality, which retains not only the ownership of the facilities but also the right to define the water supply policy through its territory¹⁷⁰.

The private company manages and operates the service at its own risk. Its remuneration level is stipulated in the leasing contract as a part of the sales price of water paid by consumers. To turn a profit, the company must keep operating expenses below the income received from the sale of water. As owner of the facilities, the municipality must bear the burden of all new investment outlays, which must also be financed through the sale of water. The price of water is accordingly divided into two parts: the "company" part

¹⁶⁹Bustarret, J. 1992. Management of French Water Supply and Sewerage Systems. In: Saarikoski, K (editor). Finnish - French Symposium on Water Supply and Sewerage. VTT Symposium 129. Technical Research Centre of Finland (VTT), Painatuskeskus, Helsinki. Pages 26 - 31.

¹⁷⁰Bustarret, J. 1992. Management of French Water Supply and Sewerage Systems. In: Saarikoski, K (editor). Finnish - French Symposium on Water Supply and Sewerage. VTT Symposium 129. Technical Research Centre of Finland (VTT), Painatuskeskus, Helsinki. Pages 26 - 31.

and the "municipality" part. In practice, the company bills customers for the service and in turn pays the municipality its share. A leasing contract generally covers 12 years, and its various clauses may in some cases be modified during the life of the contract. The price is indexed on the basis of the prevailing economic conditions^{171,172}.

Other opportunities for co-operation between private companies and municipalities also exist. The municipality can buy some services, such as maintenance, from a private company. *Gérance* means a contract whereby the company gets a fixed sum from the municipality for the managing of the plant. Then the company does not take any risk. *Régie intéressée* means that the payments to the company are in relation to the profits made. *Société d'Economie Mixte* unifies public and private capital. This has become increasingly popular in France¹⁷³.

The situation in France is quite unusual: the market is dominated by three large consulting and contracting companies, and most of the waste water treatment plants are managed by them.

Compagnie Générale des Eaux, which is the biggest of these companies, distributes water to 30 million people, of which one quarter are located abroad, mainly in Spain and England. Its turnover is approximately 163 000 million French francs. It is one of the biggest environmental engineering companies in the world. It does not manufacture waste water treatment equipment¹⁷⁴. Compagnie Générale des Eaux has five subsidiaries that

¹⁷¹Bustarret, J. 1992. Management of French Water Supply and Sewerage Systems. In: Saarikoski, K (editor). Finnish - French Symposium on Water Supply and Sewerage. VTT Symposium 129. Technical Research Centre of Finland (VTT), Painatuskeskus, Helsinki. Pages 26 - 31.

¹⁷²Morange, H. 1993. Vesihuoltopalveluiden järjestelyt Ranskassa - toteuttamiskelpoisia ideoita Suomessa? *Vesitalous*, volume 34, 4. Pages 12 - 16.

¹⁷³Morange, H. 1993. Vesihuoltopalveluiden järjestelyt Ranskassa - toteuttamiskelpoisia ideoita Suomessa? *Vesitalous*, volume 34, 4. Pages 12 - 16.

¹⁷⁴Anon. 1995. Investing in the French Water Market. *World Water and Environmental Engineering*, November 1995. Page 11.

construct waste water treatment plants. Omnium de Traitements et Valorisation is the most important of these¹⁷⁵. It has a turnover of 3 000 million French francs¹⁷⁶.

Lyonnaise des Eaux Dumez is the second largest French consulting and contracting company, with a turnover of 98 600 million French francs. It distributes water to 21 million people, half of whom live abroad. Like Compagnie Générale des Eaux, it does not manufacture waste water treatment equipment¹⁷⁷. Degrémont, which is a subsidiary of Lyonnaise des Eaux Dumez, constructs waste water treatment plants¹⁷⁸. Degrémont has a turnover of 4 900 million French francs¹⁷⁹.

Saur, which is owned by the large construction company Bouygues, is the third large company. Its turnover is 8 000 million French francs. It differs from the two big companies in that it does not have a separate company constructing waste water treatment plants, and it mainly constructs small plants¹⁸⁰.

Cise is a smaller company which is also active in the French waste water treatment market. Its turnover is 3 050 million French francs¹⁸¹.

The market shares of the consulting and contracting companies can be seen in Table 6.

¹⁷⁵Carlson, S. 1990. Ympäristötekniikan tilanne Ranskassa. TEKES, Teollisuussihteeriraportti 5 / 1990. Valtion painatuskeskus, Helsinki. Page 15.

¹⁷⁶Hydroplus, April 1996 supplement, No. 62.

¹⁷⁷Anon. 1995. Investing in the French Water Market. World Water and Environmental Engineering, November 1995. Page 11.

¹⁷⁸Carlson, S. 1990. Ympäristötekniikan tilanne Ranskassa. TEKES, Teollisuussihteeriraportti 5 / 1990. Valtion painatuskeskus, Helsinki. Page 15.

¹⁷⁹Hydroplus, April 1996 supplement, No. 62.

¹⁸⁰Carlson, S. 1990. Ympäristötekniikan tilanne Ranskassa. TEKES, Teollisuussihteeriraportti 5 / 1990. Valtion painatuskeskus, Helsinki. Page 15.

¹⁸¹Hydroplus, April 1996 supplement, No. 62.

Table 6. Waste water treatment in France¹⁸²

Managed by	% of consumers
Municipality	65
Compagnie Générale des Eaux	16
Lyonnaise des Eaux Dumez	11,6
Saur	3,5
Cise	3,5

For French engineering companies, 1995 saw a slackening of the municipal market that is explained by several factors: municipal elections, revised investment programmes, and local government indebtedness. France has also had to cope with a corruption scandal. At the moment there are only small projects going on in France. The only big projects are revampings. The most important of these is the revamping of the waste water treatment plants in Paris. Since there are not many projects in France the big consulting and contracting companies are developing their exports. Most of these companies already earn a significant proportion of their turnover on world markets, e. g. Degrémont 60 %, and Saur International 40 % of its turnover¹⁸³.

Approximately one fifth of the waste water treatment plants are stabilisation ponds. These are usually situated in small municipalities with a combined sewerage system or receiving diluted waste water. Most of the stabilisation ponds were built in the 1980s¹⁸⁴.

¹⁸²Morange, H. 1993. Vesihuoltopalveluiden järjestelyt Ranskassa - toteuttamiskelpoisia ideoita Suomessa? Vesitalous, volume 34, 4. Pages 12 - 16.

¹⁸³Chesnot, C. 1996. Les européens à la recherche d'un second souffle à l'export. Hydroplus, April 1996, No 62 special issue. Pages 16 - 19.

¹⁸⁴Racault, Y, Boutin, C & Seguin, A. 1995. Waste Stabilization Ponds in France: a Report on Fifteen Years Experience. Water Science & Technology, volume 31, 12. Pages 91 - 101.

Bioreactors have been used in France for a long time. Research on biological nitrogen removal in bioreactors is being carried out. For example, Omnium de Traitements et Valorisation has developed a small reactor which nitrifies and denitrifies¹⁸⁵. Degrémont has a biofiltration process called BIOFOR. The method is quite widely used in France¹⁸⁶. It uses aeration but Degrémont has its own air diffusers called Oxazur. These are medium bubble air diffusers specially developed for attached growth reactors. Omnium de Traitements et Valorisation has also developed a method called Biocarbhone, which purifies waste water through filtering it. Biostyr is a compact method developed by Omnium de Traitements et Valorisation¹⁸⁷. Omnium de Traitements et Valorisation markets also Oxytube air diffusers which are rather expensive. Degrémont has also been developing anaerobic processes. Its process is called Anaflux¹⁸⁸.

Most of the international aeration equipment manufacturers are present in the French market. Sanitaire and Gesellschaft für Verfahren der Abwassertechnik mbH are the most important disc diffuser brands. Frings is also active in France. There are also jet aerators. The large consulting and contracting companies also have their own aeration equipment. Surface aerators and Dipair static tube aerators are common in the pulp and paper industry. In order to succeed in France, the aeration equipment manufacturers usually have to sign a contract with one of the big consulting and contracting companies. Face to face contacts are necessary when doing business in France.

¹⁸⁵Carlson, S. 1990. Ympäristötekniikan tilanne Ranskassa. TEKES, Teollisuussihteeriraportti 5 / 1990. Valtion painatuskeskus, Helsinki.

¹⁸⁶Jepsen, Sven. Managing director, Philipp Müller GmbH, Filiale Hannover. München, 1996-05-09.

¹⁸⁷Carlson, S. 1990. Ympäristötekniikan tilanne Ranskassa. TEKES, Teollisuussihteeriraportti 5 / 1990. Valtion painatuskeskus, Helsinki. Page 16.

¹⁸⁸Carlson, S. 1990. Ympäristötekniikan tilanne Ranskassa. TEKES, Teollisuussihteeriraportti 5 / 1990. Valtion painatuskeskus, Helsinki. Page 17.

4.6.2.3 Italy

Individual countries and regions report differing trends. Italy, along with countries like Spain, France, and Great Britain, regards the solution of its water and sewage problems as the most urgent environmental problem¹⁸⁹.

The management of water resources in Italy is characterised by high fragmentation. The division of authority between many local administrations results in frequent conflicts. Fragmentation makes the decisions more complex due to local interests and consensual problems. As a result, the time span of a project from tender to construction can be very long¹⁹⁰.

The Galli law (36/1994) defines new principles for water resources management. The most important point of the law is the rationalisation of water treatment. The management of public services, such as aqueducts, sewers and treatment plants, of a given area is centralised in one bureau to form a closed water cycle. The areas are specified by hydrological basins. The management of various services is integrated and consequently the dimensions should be optimal from the physical, demographical, technical and administrative points of view¹⁹¹. The law turns water into a business in which private companies can also take part. The regions may decide who is in charge of water resources management. The country is divided into water resources management basins called bacini d'utenza according to the number of people using the service, not according to municipalities. The objective is to form approximately one hundred waterworks, instead of the present 5 500 or so. The size of one waterworks would be equivalent to approximately 500 000 inhabitants¹⁹². This should make the business profitable. The annual turnover of the sector will be at least 66 000 million Finnish marks. Along

¹⁸⁹Anon. 1995. Market survey. Helmut Kaiser Unternehmensberatung, Tübingen, FRG.

¹⁹⁰Ruokonen, M. 1994. Study Concerning Waste Water Treatment and Sludge Handling in Italy. TEKES, Office for Science and Technology in Milan. Page 4.

¹⁹¹Ruokonen, M. 1994. Study Concerning Waste Water Treatment and Sludge Handling in Italy. TEKES, Office for Science and Technology in Milan. Page 34.

with Italian companies, English and French companies in particular have been interested in the Italian water business¹⁹³. The Galli law is a skeleton law, and in order to realise these principles, many lesser statutes and laws are needed, and this will still take some time.

The assignment of a project usually takes place by tender, more rarely by concession. Concession denotes a contract in which all the rights and duties of the municipality in a given sector are transferred to a private company. A concession provides more advantages and responsibilities for the participating companies, but its usefulness has been reduced by a directive of the European Union which asserts that a concession does not respect the principles of competition and transparency¹⁹⁴.

A contract usually comprises the starting-up of the plant, and very often the management of the plant for a period of 1 to 2 years as well as training of the staff. After that, the municipality, a consortium of municipalities, or a company specialised in this field takes over the management. Sometimes the company which has constructed the plants continues to manage it¹⁹⁵.

Italian legislation on environmental protection is considered quite strict. The absence of control is the main problem. The application of directive 271/1991, which should occur soon, should make control more effective¹⁹⁶. This means there should be a great deal of investment in waste water treatment plants in the coming years. The corruption scandal has delayed the investments. It halted the projects in the waste water treatment field for many years, but in 1996 these activities have been resumed.

¹⁹²Rautanen, S-L. 1995. Vesihuollon nykytila Suomessa ja viidessätoista muussa Euroopan maassa. *Vesitalous*, volume 36, 6. Pages 1 - 7.

¹⁹³Anon. 1994. *Täällä Italia, ympäristöuutiset*, 1994 (2). Page 3.

¹⁹⁴Malaman, R & Paba, S (editors). 1993. *L'industria verde. Studi e ricerche CCCXVII*. Bologna, Il mulino. Page 153.

¹⁹⁵Malaman, R & Paba, S (editors). 1993. *L'industria verde. Studi e ricerche CCCXVII*. Bologna, Il mulino. Page 153.

The adoption of directive 271 should change the waste water treatment in Italy. About 15 000 million Finnish marks should be invested in treatment plants for removal of organic substances. Another 4 800 million Finnish marks are needed for extension of tertiary waste water treatment, that is removal of nitrogen and phosphorus from water discharged into sensitive areas¹⁹⁷. There are about 2 500 plants that need a tertiary treatment extension¹⁹⁸.

In 1989, the concept of hydrological basins was introduced into the legislation. The French system was used as a pattern. The six national basins are Po, Adige, Alto Adige, Arno, Tevere, and Liri - Garigliano. In addition, there are 18 interregional basins, and numerous regional basins. The Po river basin is the largest and most important one because of the industry situated in its catchment area. The basins do not have the same boundaries as the regions.

Supervision of individual catchment basins is placed in the hands of a Basin authority, *Autorità di Bacino*. It is responsible for the protection and preservation of the basin, as well as for the improvement of the qualities of soil and water. There have been organisational and logistical problems. The concept of basins, in addition to the Galli law, should have simplified the management of water resources. However, it seems that the basins have complicated the situation even further, and the basin authorities will be suppressed^{199,200}.

¹⁹⁶Ruokonen, M. 1994. Study Concerning Waste Water Treatment and Sludge Handling in Italy. TEKES, Office for Science and Technology in Milan. Page 34.

¹⁹⁷Anon. 1993. Giornate di studio europee sullo smaltimento dei fanghi di depurazione. *Energia e innovazione*, n. 10 / ottobre. Pages 132 - 133.

¹⁹⁸Canziani, R, Capria, A & De Cesaris, A L (editors). 1991. La nuova direttiva comunitaria sulle acque reflue urbane negli stati membri della Comunità Europea, *impatto istituzionale e tecnico economico*, Report 91/01. Milan, Istituto per l'ambiente. Page 34.

¹⁹⁹Ruokonen, M. 1994. Study Concerning Waste Water Treatment and Sludge Handling in Italy. TEKES, Office for Science and Technology in Milan. Page 4.

According to the Merli law (319/1976), the responsibility for environmental crimes is personal. This means that in all industrial and urban settlements a person must be named who is responsible for the environment. This person can then be penalised for infractions. The penalties are usually financial, but may also lead to imprisonment²⁰¹.

There are about 5 000 waste water treatment plants in Italy. Most of the plants have been constructed during the 1980s. About 80 % of these plants have biological treatment. Only 60 % of the urban waste water is treated in Italy²⁰². Most of the plants are small or very small, and they very often suffer from lack of management²⁰³. The situation in many municipalities is rather urgent²⁰⁴. For example Milan, which is the biggest industrial city in the country, does not yet have any waste water treatment plant. Its treatment plant construction project was started as long ago as the 1970s but the plant has still not been commissioned.

Only 36 municipal waste water treatment plants in Italy have the capacity to handle more than 250 000 population equivalents. Nopon Oy has supplied its aeration equipment to around 100 Italian waste water treatment plants²⁰⁵. The market for construction of new waste water treatment plants and

²⁰⁰Rautanen, S-L. 1995. Vesihuollon nykytila Suomessa ja viidessätoista muussa Euroopan maassa. *Vesitalous*, volume 36, 6. Pages 1 - 7.

²⁰¹Ruokonen, M. 1994. Study Concerning Waste Water Treatment and Sludge Handling in Italy. TEKES, Office for Science and Technology in Milan. Pages 3 - 4.

²⁰²Canziani, R, Capria, A & De Cesaris, A L (editors). 1991. La nuova direttiva comunitaria sulle acque reflue urbane negli stati membri della Comunità Europea, impatto istituzionale e tecnico economico, Report 91/01. Milan, Istituto per l'ambiente. Page 25.

²⁰³Anon. 1992. Relazione sullo stato dell'ambiente. Ministero dell'Ambiente, Istituto Poligrafico e Zecca dello Stato. Page 177, 184.

²⁰⁴Ruokonen, M. 1994. Study Concerning Waste Water Treatment and Sludge Handling in Italy. TEKES, Office for Science and Technology in Milan. Page 34.

²⁰⁵Reference database of Nopon Oy.

revamping of existing plants is expected to expand, especially in the northern regions of the country²⁰⁶.

There are no statistics on the waste water treatment in industry. The situation in the biggest industrial companies is considered quite good. They have usually provided for waste water treatment by constructing purification plants, either on their own or in co-operation with other companies. The biggest steel plants, and the petrochemical, metal, and mechanical industries have been the precursors. The major shortcomings exist in the small and medium sized companies. The problem is that most Italian companies are of small or medium size. The shortcomings are usually due to a lack of financial resources. In the private construction projects, technical quality is more important than in public projects where price plays a more dominant role. The dimensions of the plants are usually smaller in private projects, and the time needed for completion is shorter. In industry, most of the work will consist of improvements and revamping²⁰⁷.

Most of the biggest paper mills in Italy have a chemical - physical waste water treatment plant. Many mills also have biological treatment. Generally, the plants in northern Italy take care of waste water treatment, and all comply with the laws. In the South, and in smaller companies, the situation can be worse. Water is so inexpensive that the companies have not thought about closing the water cycle. Legislation does not encourage the recycling of water. It does not place any limits on the quantity of water used, but only on the quality. Of course, the quality is lower if the water has been recycled many times²⁰⁸.

²⁰⁶Ruokonen, M. 1994. Study Concerning Waste Water Treatment and Sludge Handling in Italy. TEKES, Office for Science and Technology in Milan. Page 27.

²⁰⁷Ruokonen, M. 1994. Study Concerning Waste Water Treatment and Sludge Handling in Italy. TEKES, Office for Science and Technology in Milan. Page 34.

²⁰⁸Ruokonen, M. 1994. Study Concerning Waste Water Treatment and Sludge Handling in Italy. TEKES, Office for Science and Technology in Milan. Pages 25 - 26.

Most of the international aeration equipment manufacturers are present in the Italian market. Disc diffusers are very common in Italy, and Sanitaire, Envicon, and Gesellschaft für Verfahren der Abwassertechnik mbH are active there. In addition, there are rather a few Italian competitors. The most well known of these is Tagliaferri e Reschini, which markets disc and tube diffusers. Società Italo - Britannica Acque and Italprogetti produce aeration equipment as well. Frings and Messner are also active in Italy²⁰⁹.

Many private companies have had problems in doing business with the Italian public sector, related especially to delays in payment. In addition, bureaucratic slowness, red tape, delays the implementation of the projects, with uncertainty in regard to the date of initiation and the risk that the budget is not kept to²¹⁰.

A medium-sized public waste water treatment plant project takes about four years: two years for the actual construction and at least two years for the preliminary phase from tender to the finding of financing. Price is a relevant competitive factor when the contractor for the public sector is selected²¹¹.

One problem is the limitation of subcontracting which, according to the statutes, may not be more than 40 % of the total value of the plant, excluding components. This fact forces the companies to form a group, and for major projects consortia of companies are created²¹².

According to an estimation²¹³, there are about 300 companies operating in the field of contracting for waste water treatment plants. This number

²⁰⁹Hannu Kosonen. Area manager, Nopon Oy. 1996-08-05. München.

²¹⁰Ruokonen, M. 1994. Study Concerning Waste Water Treatment and Sludge Handling in Italy. TEKES, Office for Science and Technology in Milan. Page 11.

²¹¹Malaman, R & Paba, S (editors). 1993. L'industria verde. Studi e ricerche CCCXVII. Bologna, Il mulino. Page 133.

²¹²Ruokonen, M. 1994. Study Concerning Waste Water Treatment and Sludge Handling in Italy. TEKES, Office for Science and Technology in Milan. Page 11.

²¹³Malaman, R & Paba, S (editors). 1993. L'industria verde. Studi e ricerche CCCXVII. Bologna, Il mulino. Page 134.

includes big construction and engineering companies, as well as smaller companies that construct plants of smaller dimensions, and companies that produce components and parts for use in the waste water treatment industry. The number is an estimate since it is very difficult to define which companies are really specialised in this field, particularly in the case of smaller companies. A total of about 30 companies account for two-thirds of the whole turnover of the water treatment industry.

A few of the big contractors operate in many industrial sectors and receive only a minor part of their turnover from the environmental engineering sector. Among these are the ones with public capital, such as Ansaldo (Iri), Snamprogetti (Eni), and Jacorossi (controlled by Fintermica and Agip Petroli), as well as the ones with private capital, such as Tpl, Foster & Wheeler, Italmimpianti, and Tecnimont. Snamprogetti and Tecnimont operate more as engineering companies than as true contractors. Contractors make more use of solid technological know-how by acquiring licences and by developing their own patents. Engineering companies use the technologies they consider most suitable for every individual case. Engineering companies often only draw up the design for a plant while the contractors take on turnkey projects. This difference is useful in identifying the organisation of the company, even if there is a rule that in order to be allowed to take part in tenders in Italy, a company should be a member of the Italian National Register of Contractors (*Albo dei costruttori*, category 12 A for water distribution networks, sewage networks, and water treatment plants), and in consequence all the major companies are classified as contractors²¹⁴.

Some of the companies that are specialised in environmental engineering are part of large or medium sized Italian groups such as Fiat (Fisia, previously Castagnetti), Danieli (Daneco), Gruppo Acqua (Società Italo - Britannica Acque), Ferruzzi (Tecnimont), and Maffei (De Bartolomeis). Secit, Unieco,

²¹⁴Ruokonen, M. 1994. Study Concerning Waste Water Treatment and Sludge Handling in Italy. TEKES, Office for Science and Technology in Milan. Page 28.

and other smaller co-operatives that are active in contracting belong to the Association of Co-operatives²¹⁵.

Foreign companies are showing increasing interest in the Italian market. A few foreign groups have a branch in Italy. For example, there are Générale des Eaux (Polytec Valorizzazione Ambientale, Omnium de Traitements et Valorisation Filiale Italiana, Siemec), Lyonnaise Des Eaux (Degrémont), Ionics Inc. (Ionics Italba), Foster & Wheeler (Foster & Wheeler It.), Passavant Werke (Passavant Impianti), and Technip (Tpl, previously Technipetrol)²¹⁶. Termomeccanica belongs to a Spanish group.

Many contractors use technologies they themselves have developed and patented, or technologies that have been developed by the foreign parent company. However, most of the technologies seem to come from abroad, as demonstrated by the large number of foreign licences acquired by Italian companies. Most of the licences come from the United States, Germany, and Northern European countries²¹⁷.

Vertical integration is not very important at present, but the opportunity to supply a vast collection of products is an essential competitive element. Maintaining the level of turnover in situations of fluctuating demand is the advantage of horizontal integration. Variations in demand are characteristic of the waste water treatment sector²¹⁸.

²¹⁵Ruokonen, M. 1994. Study Concerning Waste Water Treatment and Sludge Handling in Italy. TEKES, Office for Science and Technology in Milan. Pages 29 - 30.

²¹⁶Ruokonen, M. 1994. Study Concerning Waste Water Treatment and Sludge Handling in Italy. TEKES, Office for Science and Technology in Milan. Page 30.

²¹⁷Ruokonen, M. 1994. Study Concerning Waste Water Treatment and Sludge Handling in Italy. TEKES, Office for Science and Technology in Milan. Page 30.

²¹⁸Ruokonen, M. 1994. Study Concerning Waste Water Treatment and Sludge Handling in Italy. TEKES, Office for Science and Technology in Milan. Page 33.

5 Reliability Analysis

The findings in this study are based on the literature, interviews with the customers, and discussions within Nopon Oy. The literature used in this study has been selected for its freshness, coverage, and reliability. Written sources have been identified through database searches, and by scanning recent volumes of several well known scientific journals. In many cases the ideas presented have enjoyed broader support than indicated by the footnotes. This applies especially to the chapter on trends in the waste water treatment market.

In regard to the reliability of this study, the sample size in the interviews can be criticised. The quantitative results are not as valuable than the qualitative results since the sample was not very large. Tendencies for the importance of the various factors can still be derived from the quantitative approach. One source of error is that the distributors all represent Nopon Oy. The replies may have been different if distributors of other types of aeration equipment had been interviewed.

The selection of the case countries can also be criticised. Only European countries were examined. It may have been more interesting to study the local market in a country which is not as familiar to Nopon Oy.

6 Conclusions

There are various aeration techniques in the market. This study provides a brief description of 17 aeration equipment which have been evaluated as important competitors. The aeration equipment is classified according to the need for compressed air. This classification should prove more logical than the ones used previously.

The selection of aeration equipment for a waste water treatment plant is a complex process. Many people are involved. Eight types of customers for aeration equipment are defined in the study:

- research centres
- municipal councils
- municipal experts
- industrial experts
- plant operators
- consultants
- contractors
- distributors

These persons have different interests. The features of aeration equipment and manufacturers have been divided into factors, and the importance of each factor to the customers has been evaluated. The factors affecting the selection of aeration equipment are divided into process, product, service, company, and local factors. The major factors are shown in Figure 29.

The selection of the process eliminates desire and generic competitors. Product, company, service, and local factors are more important from the point of view of the aeration equipment manufacturer. The relative importance of product, service, and company related factors is evaluated in Table 7. The evaluation is based on interviews with researchers, plant operators, consultants, contractors, distributors, and municipal and

industrial experts. The interviewed people were asked to evaluate statements in a scale of 1 to 4, with 4 being very important and 1 not important at all.

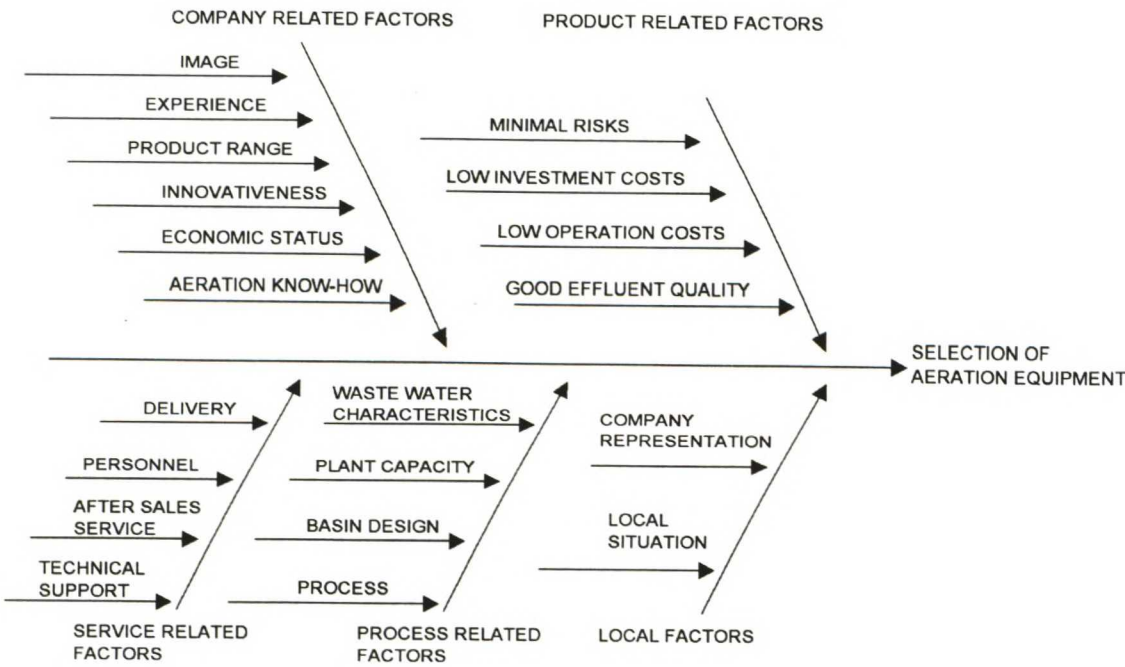


Figure 29. Factors affecting the selection of aeration equipment

Table 7. Product, service and company related factors and their relation to the customers

	In total
PRODUCT	3,51
Good effluent quality	3,76
Low investment costs	3,54
Low operation costs	3,49
Minimal risks	3,41
SERVICE	3,52
Technical support	3,45
Personnel	3,73
Delivery	3,24
After sales service	3,70
COMPANY	3,36
Image	3,34
Innovativeness	3,23
Aeration know-how	3,56
Product range	3,48

It can be seen that there are no great differences between the product, service, and company related factors. There are only three singular features

that have gained more support than the others. These are good effluent quality, personnel, and after sales service.

The differences between the customers are not shown in Table 7. Table 8 presents the differences in importance of the factors to each customer. There are, however, no great differences. All the customers, except the research centres, regard product related factors as the most important. Service and product related factors are approximately as important to the research centres. One explanation for the similarity of the values presented in Table 8 can be that individual liking affects the decisions more than the role one plays in the purchasing process. Another reason is the difference of projects to construct a waste water treatment process. If the project is very simple, it is predictably the price which is crucial. If the project is not simple, the customer most probably appreciates the aeration know-how of the manufacturer.

Table 8. Importance of product, service, and company related factors to various customers

	PRODUCT	SERVICE	COMPANY
Research centres	3,87	4,00	3,43
Municipal experts	3,76	3,61	3,61
Industrial experts	3,56	3,51	3,29
Plant operators	3,47	3,43	3,43
Consultants	3,34	3,30	3,15
Contractors	2,90	2,53	2,67
Distributors	3,68	3,57	3,44

There is an indication that product related factors are important for all the customers. However, when the various product related factors are analysed in Table 7, no one clear factor can be found to be determinant. Many customers value good effluent quality but investment and operation costs are also important.

By examining the case countries Finland, France, and Italy, it can be concluded that these three European countries have quite different waste

water treatment markets. All the three countries are in the process of privatising their waste water treatment plants. In France, approximately 40 % of the waste water treatment plants are managed by private companies. Finland is not as radical; it is very slowly going to change the municipal waste water treatment plants into independent units. In Italy, there is a law which enables private companies to manage waste water treatment works but the law is not yet in effect.

Due to the European Union, Finland, France, and Italy should have the same environmental legislation. The situation is, however, quite different in these countries. In Finland and France, all the major waste water treatment plants have already been constructed, and only revamping will be carried out in the future. Revamping is mainly caused by the obligation to remove nitrogen from the waste water. In Italy, many completely new plants are still required.

It would be interesting to study the product, service, and company related factors in the target countries. It would require a large sample to discover the differences between the customers in various countries. Unfortunately, it was not possible to do it for this study.

7 Summary

The research problems of this study can be expressed as questions:

- What kind of aeration equipment is there in the market?
- Which is the best way to classify aeration equipment?
- Who are the customers for the aeration equipment manufacturer?
- Which characteristics of aeration equipment are valuable to the customers?
- Are there differences between the valuations of aeration equipment characteristics by various customers?

The competitors can be classified into desire, generic, form, and brand competitors. When aeration equipment is being considered, other methods of purifying waste water become desire competitors of it. Trickling filters and anaerobic processes are examples of methods that do not require aeration.

Aeration equipment is classified in this study into two classes according to the aeration efficiency, viz. aeration equipment with compressed air and equipment without compressed air. These are generic competitors of each other. They present different basic ways of fulfilling the same desire. Generic competitors usually do not compete with each other in the tender for a waste water treatment plant. Since the products of Nopon Oy, Nopol[®] disc diffusers and Nopol[®] submerged aerator mixers, use compressed air, this form of equipment is treated in more depth.

Different aeration methods are form competitors. Form competitors of Nopol[®] products are other forms of aeration equipment with compressed air. Brand competitors are aeration equipment which is similar but which is manufactured by different companies. Brand competitors of Nopol[®] disc diffusers are other disc diffuser brands and those of Nopol[®] submerged aerator mixers other turbine aerators with compressed air.

The characteristics of aeration equipment can be divided into process, product, service, company, and local factors. Desire and generic competitors are usually eliminated by process factors. After the waste water treatment process has been decided upon, the product, service, company, and local factors determine the aeration equipment selection. Product, service, and company factors are evaluated in interviews with the customers. The local market is examined in three target countries: Finland, France, and Italy.

Research centres, municipal councils, municipal experts, industrial experts, plant operators, consultants, contractors, and distributors are identified as customers for the aeration equipment manufacturer. In this study, no clear differences between these customer groups in relation to the aeration equipment characteristics could be found. It seems that personal liking affects the selection more than the role one plays in the purchasing process.

Local factors influence the selection of aeration equipment markedly. Local factors consist of company representation and of the local market. There are significant differences between the aeration equipment markets in Finland, France, and Italy.

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