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The municipal continuum: Research on maritime water pollution in Helsinki in the 20th century

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In general, the history of environmental research is not known very well. Our study contributes to filling this gap by focusing on the history of the methods that were used during the 20th century to study the state of the urban sea area in Helsinki, Finland. From the beginning of the past century, the methodological basis of municipal water pollution studies in Helsinki was broad, involving the use of physical, chemical, hygienic and biological methods. Since 1904, municipal laboratories have overseen and conducted most physico-chemical and bacteriological studies of pollution of urban watercourses, and they have done regular annual sampling since 1947. In the 1920s and 1930s, the municipal laboratories cooperated with the University of Helsinki and, secondarily, with the Helsinki University of Technology in order to develop the skills and manpower that were required in order to conduct pollution studies. Statutory monitoring was initiated in the mid-1960s, and it continues today.

Introduction

"Was marine pollution studied prior to the 1970s?" This question, which was asked by students of hydrobiology during a recent seminar at the University of Helsinki, indicates the lack of field-specific historical knowledge in the curricula of environmental studies. At the same time, however, study of the history of environmental science can provide valuable information to anyone who is interested in tracing the long-term changes in the environment.

All in all, the long-term interaction between man and nature in significant local contexts is a rather neglected topic in the environmental sciences. Only a few studies in the history of the environmental sciences have explored anthropogenic changes in the environment. This is so because mainstream research on the history of science focuses on natural phenomena, particularly on flora and fauna, *per se*, without showing any particular interest in human-induced changes (*see* Bowler 1992). One consequence of the unfortunate neglect of the history of environmental science is the prevailing notion that scientific studies of environmental problems were not initiated until the 1970s, or even later.

We argue that studies of environmental issues have a long history, particularly in regard to urban problems. Case studies of the historical trajectories of the ways in which cities have studied and tackled these issues are useful because they reveal the long, deep roots of the development of scientific studies of environmental changes that man has caused. We claim that water quality studies initiated and supported by cities, i.e. municipalities, have the longest continuous tradition of studies of the state of urban environment in general.

The history of medical and hygienic studies of drinking water of the 19th century was studied in detail (Luckin 1986, Hietala 1987, Hamlin 1990), but the history of research on water pollution was discussed by urban environmental historians as a rule only on a very general level (Tarr 1984, Melosi 2000). Nevertheless, some publications are devoted to the history of scientific studies of the pollution of urban water bodies (Wood 1982, Laakkonen and Laurila 2001) and lakes and rivers (Sheail 1996, 1998, 2000, McGucken 2000). The history of the eutrophication of the sea area off Helsinki has been reconstructed from today's point of view (Viitasalo 1975, Finni *et al*. 2001). The history of water pollution research in other cities in the Baltic Sea region had been studied by a project entitled The Sea and the Cities, and the results were published in a special issue of *Ambio* edited by Laakkonen and Laurila (e.g. Arnesen 2001, Cetkauskaité *et al*. 2001, Johansson and Wallström 2001, Primakov and Nikolaenko 2001). Yet, Helsinki is the only city in the region where the history of hygienic, chemical, physical and biological methods has been examined so far.

Scientific research is done by human beings and is thus a social and historical construction (Kuhn 1962). The cultural change from an agricultural to an urban-industrial society is also reflected in the different fields of science. The dual process of modernisation and professionalisation took place in science mostly in the 19th century and early 20th century. Modernisation means here a gradual change from descriptive natural philosophy towards empirical studies (Laakkonen 2001). Professionalisation (Larson 1977, Hietala 1987) of science signifies the development of new tasks and professions, research facilities, scientific organisations and identities. Each historical era has its particular ideals, paradigms and methods, which the people of that time consider to be more rational, i.e. better, than the previous ones.

Our aim was to study the history of pollution research of the urban sea area of the city of Helsinki. We focused on the period prior to 1966 and beginning of statutory monitoring of the sea water in and near Helsinki. The following questions are addressed: (1) When did scientific research on pollution in this urban sea area start? (2) What was studied, how often and which methods were used to detect pollution? Our aim was to provide the first comprehensive description of the development of marine pollution research in Helsinki in the 20th century.

Material and methods

We collected all published and unpublished reports and material on the water research done in the city of Helsinki. For most of the 20th century, we found no specific scientific publications on urban pollution studies. Instead, most studies were published in various municipal report series, or were not published at all. The historical bibliography issued by the Water Conservation Laboratory was helpful in bringing together the published material (Pesonen 1988). The unpublished studies were traced with the help of hints found in newspapers and publications, annuals and minutes of municipal administrative agencies. Unpublished research reports and related background material were found in the archives of the City of Helsinki (including the archives of the Board of Health), the archives of the Laboratory of Sanitary Studies and of the Municipal Water Works, the archives of the Department of Public Works, the Central Archives of the University of Helsinki, the archives of the Central Laboratory Ltd., and the archives of the Finnish Institute of Marine Research.

We focused on the scientists who conducted the research, the research methods that they used, and the conclusions they drew. The main emphasis of our article is, however, on an examination of their research methods in order to determine what parameters they used and measured to detect and define pollution. We used qualitative contents analysis as a research method. As two original research reports could not be located, we have described them on the basis of secondary sources. We collected data on study samples from the archives and the reports in order to obtain an overview of the main quantitative changes in

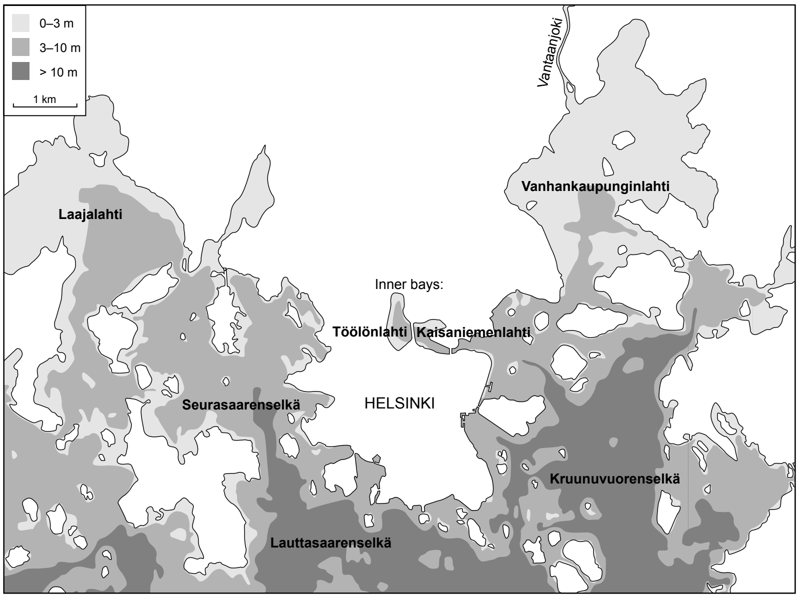

Fig. 1. Helsinki and the adjacent bay areas in 1922. This shallow sea area served as a recipient for domestic wastewater of 150 000 inhabitants and for Finland's largest industrial centre. Source: Witting 1923.

research over time. The Environment Centre of the City of Helsinki provided data regarding the monitoring era, from 1966 up to the present. In general, the unpublished and published reports appear to be relatively good sources for the purpose of reconstructing the main qualitative and quantitative changes in research over time.

The sea area off Helsinki and its state at the turn of the 20th century

The study area is the sea area off Helsinki, the capital of Finland, which is located on the northern coast of the Gulf of Finland. There are several shallow bays on both sides of the city as well as within its limits (Fig. 1). The average depth of the inner bays is only 1–3 metres, and less than 20 metres in the outer bays. Even the open sea south of the city is shallow, being less than 30 metres deep. Salinity ranges between 0‰–7‰. The Vantaanjoki, which is the only river in the region, flows into the eastern bay (average annual flow 16.9 $m^3 s^{-1}$ in 1970–1990) (Pesonen *et al*. 1995).

In the beginning of the 20th century Helsinki was a fast-growing industrial and governmental centre. Its population tripled in three decades, reaching over 130 000 inhabitants in 1910 (Åström 1956). During the same period, the number of large industrial plants almost quadrupled, increasing to almost 200 facilities by 1910 (Kovero 1955). In 1878 the municipal water works started to pump water from the Vantaanjoki into the town, and soon thereafter the first municipal sewers were laid. The amount of pumped water and concomitant wastewater loadings increased as well.

The Board of Health of the City of Helsinki, which was responsible for the sanitary conditions in the city at that time, established a Laboratory of Sanitary Studies in 1883. In the beginning its tasks were mainly connected with controlling the quality of foodstuffs and drinking water, but later also with monitoring and solving pollution problems (Enqvist 1974). The first scientific pilot study on the pollution of urban water courses was made in 1888 by the director of the laboratory, Ossian Aschan, Ph.D. He found that horse manure, which was being transported via sewers, was largely responsible for the formation of thick sediments in the harbour basins (Aschan 1888). At that time the use of water closets was forbidden by the City Council to protect the urban watercourses (Laakkonen 2001).

However, in 1904 drainage of human waste into the sewers was permitted, and the water closet soon became a common comfort. As a result, that same year the research programme of the municipal laboratory was expanded to include hygienic studies of the increasing sewage loads on washing, rinsing and bathing sites located along the sea shores. The director of the laboratory, Allan Zilliacus, was a chemist, and he had two assistants for bacteriological and chemical research (Enqvist 1974).

Water samples were collected from the inner bays and two other sampling locations once a week, altogether 276 samples in 1904, 162 in 1905 and 38 in 1906. Temperature, chloride, permanganate consumption (today chemical oxygen demand), colour and transparency were measured. According to the results, the water quality was generally satisfactory during the summer months, but it worsened during the wintertime until ice break-up, after which the water quality soon improved. However, during the summer a faint mustiness and the odour of hydrogen sulphide (H_2S) emanated from the water, and due to algae the water of the inner bays looked green (Bergman 1908).

The city physician, Wilhelm Sucksdorff (also the first professor of hygiene at the University of Helsinki), had his doubts about the quality of the seawater. The results of his quantitative studies of the bacteria content of 104 samples taken from the rinsing houses in 1907 were alarming. Due to the threat of new typhoid epidemics, he recommended that these studies be continued and expanded (Enqvist 1974).

The first comprehensive study, 1908

Sucksdorff, Zilliacus and Aschan, who was now professor of chemistry at the Helsinki University of Technology, were active in launching a new study of pollution in the sea area. However, the first extensive evaluation of the water quality of the shore waters was planned by the young temporary director of the laboratory, Gustaf Konrad Bergman. Although he was a chemist, Bergman had also studied botany. As he had become acquainted with modern hygienic water analysis methods in Hamburg, the methodological basis of his work was now broad, consisting of bacteriological, physico-chemical and biological analyses (Laakkonen 1999).

Bergman's sampling area consisted of eight off-shore sites and 27 sites along the shores. The sampler was specially constructed for the project according to German specifications. A total of 1106 samples were taken at the depths of 0.5, 1.5 and 3 metres. He took two chemical samples and one bacteriological sample at each site and depth. In addition he analysed some plankton samples from the inner bays. He measured wind direction, water level, temperature, transparency, oxygen, pH, permanganate consumption, chloride, coli bacteria, ammonia, and nitrate, and he also described the appearance and colour of the water (Bergman 1908).

Bergman also conducted some experiments on oxygen demand. As he noted in his report, "according to e.g. Spitta 1906, and Grosse-Bohle 1906, dissolved oxygen and oxygen demand indicate the extent to which the river water is polluted by organic substances. That is the reason why I decided to use the same method in our harbours." Bergman used the Winkler method to analyse dissolved oxygen, and he also determined the saturation percentage. Oxygen demand, i.e. the decrease of oxygen content, was measured over 24 hours at 23–24 °C (Bergman 1908). From the point of view of current research methodology, Bergman was conducting what would generally correspond to a BOD_1 study.

Despite its limited scope, Bergman's work turned into a study of the general hydrobiology of the urban sea area of Helsinki. His main concern, however, was pollution. Bergman concluded that bacteria and ammonia readings were the best indication of the level of pollution in certain places: the values were 5–15 times, even 160 times higher than normal. In addition to giving detailed numbers, Bergman painted a vivid and detailed picture of the pollution situation in the Helsinki sea area. According to him "a belt of sewage water" was surrounding the cape of Helsinki because all sewer outlets ended at the shores, and winds and currents kept the sewage water near the shoreline and hindered its dilution. Only the southern and western bay areas were rather undisturbed.

The state of the semi-enclosed inner bays of the city was memorably bad. During the summer, Bergman observed the changes in the amount of different species of algae in relation to the chemical parameters. In June Bergman did not observe any algae in the inner bays, but his chemical analyses showed a state of extreme organic pollution, with a permanganate consumption over 90 mg l^{-1}. In July the situation had changed: because of algae blooms the water looked like "green soup". Examining a plankton sample with a microscope, Bergman found out that a filamentous blue-green alga, *Oscillatoria agardhii* (*Planktothrix agardhii*) had bloomed. The presence of that alga in the bay indicated poor water quality and spread a musty smell. By August, the situation had changed and a new species had become dominant, namely a blue-green alga, *Anabaena spiroides* (Fig. 2). The odour of hydrogen sulphide was noticeable, and the ammonia concentration was also very high (up to 16 mg l^{-1}). Bergman probably made the first pilot study of the succession of blue-green algae in a watercourse affected by wastewater in Finland. Bergman assumed that nitrogen was the cause of algal blooms in the inner bays, because the municipal gas works were discharging approximately 27 tonnes of ammonia into the bays each year. Bergman was also the first to examine water pollution problems caused by industrial plants (Bergman 1914). In addition to Bergman's plankton observations, Kaarlo Mainio Levander, professor of zoology and founder of plankton research and hydrobiology in Finland, made some observations of the blue-green algal blooms in the inner bays based on random samples (Levander 1908, 1913, 1918).

In 1911, as the inhabitants of the city were actively using seawater for a number of different purposes at the time, the municipal laboratory made a hygienic study of the swimming areas along the shores around the cape of Helsinki. The results of this study showed that the seawater near the downtown area was so polluted that no new swimming facilities places should be constructed in the area (Hufvudstadsbladet 29 September 1911 and 1 November 1911). According to another study made that same year, the rinsing places were also found to be contaminated (Helsingin kaupungin tilasto 1911).

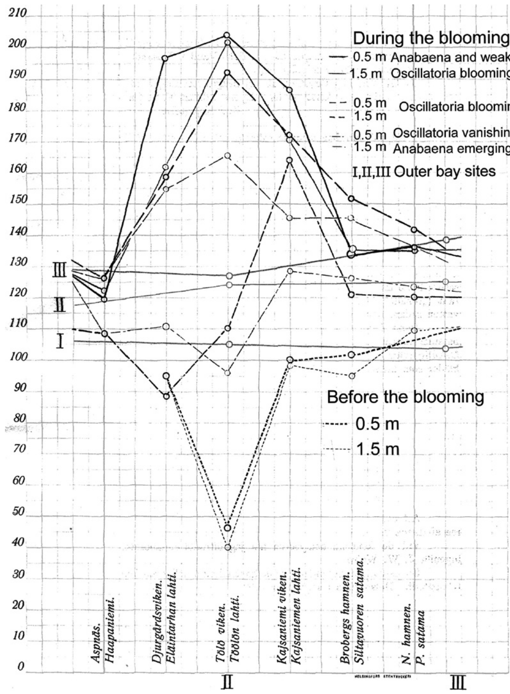

Fig. 2. Oxygen saturation in the hypereutrophic inner bay area and its vicinity in summer 1908. The oxygen saturation varied with the blooming of different algae. Prior to the blooming oxygen saturation was at about 100% and during blooming up to 200%. Source: Bergman 1908.

Multidisciplinary pollution research programme in the 1910s and 1920s

In 1911 the chair of City Government demanded that measures be taken to solve the pollution problems. The Board of Health recommended that hygienic, physico-chemical and biological studies of the water quality be made and that different treatment methods be investigated (Helsingin kaupunginvaltuusto 1924). In 1915 a sewage water committee was formed to find solutions to the pollution problem (Helsingin kaupunginvaltuusto 1915). The committee applied the same broad approach as Bergman had in his study, but this time the studies were carried out in co-operation with several institutions.

The water exchange in the sea area off Helsinki needed to be studied. The newly established Finnish Institute for Marine Research was given the task to examine the hydrographical conditions of the sea area. The institute collected water samples from April 1919 until May 1920 and measured temperature, chloride, oxygen and ammonium. Some experiments on biological oxygen demand were also conducted (Granqvist and Buch 1921, Witting 1923). Bergman, who was now a chemist at the Laboratory of the Municipal Water Works, conducted physicochemical experiments on the dilution of sewage water near some of the sewer outlets (Helsingin kaupunginvaltuusto 1924).

Biological studies of marine pollution were conducted by The Aquatic Biology Research Unit of the Finnish Society of Science and Letters. Professor Levander was its director. Its members included Ernst Häyrén, who had a doctoral degree in botany, and Ilmari Välikangas, a zoologist at the University of Helsinki. They studied shoreline vegetation and plankton in the Helsinki sea area.

Välikangas, who was a student of Levander, wrote his doctoral dissertation on the plankton of Helsinki in 1926, including the use of plankton species as a basis for classifying pollution. This was the first dissertation in this field in Finland. Välikangas gathered plankton samples 2–6 times during the growing season. The samples were taken mainly by nets, but some water samples were also taken. A zooplankton net was used to collect larger organisms from deeper waters. The samples were preserved in formalin and centrifuged. A light microscope was used for counting. Välikangas described the species, their annual development, and their dependence on salinity and other environmental factors (Välikangas 1926).

Välikangas adopted the saprobic system developed by Kolkwitz and Marsson (1902, 1908, 1909). The sabrobic system had been developed for use in fresh water, mainly for classifying river pollution, but Välikangas applied the system to brackish water environments. Based on comparisons of local species diversity and conditions with the German indicator list, he concluded that some species dominant in polluted seawater in and near Helsinki had different indicator values than those which Kolkwitz and Marsson had suggested. Välikangas recognised that particular plankton species were typically present in polluted bay areas in Helsinki: *Oscillatoria agardii*, *Euglena viridis*, *Cyclotella laevissima*, *Brachionus pala* and *B. angularis*. According to Välikangas the inner bay areas and the eastern side of the city were the most polluted areas in Helsinki.

Littoral macrophyte vegetation was studied by Ernst Häyrén. He investigated the submerged vegetation along the shoreline of the Helsinki cape and some adjacent islands to determine pollution. Häyrén was well qualified to make these studies because he had written his doctoral dissertation on archipelago vegetation (Häyrén 1914) and was familiar with the saprobic features of littoral vegetation (Häyrén 1910). He studied a total of 28 kilometres of urban shoreline, walking along the shores, making detailed notes on the species and their associations, and collecting samples for microscopic analysis (Hällfors *et al.* 1987). He also used the saprobic system and its associations as tools for classification of pollution by adapting the system for local flora (Häyrén 1921).

Even though algal blooms constituted an almost annual problem for the city and the relationship between blooms and nutrients was generally understood, biological methods were used to detect primarily pollution caused by organic loads. The results of the research programme of the 1920s proved that pollution had increased in areal coverage since 1908. According to ammonium and oxygen values, as well as plankton and macrophyte indicator species, the inner bays were being severely affected by sewage waters (α-mesosaprobic). The eastern bay areas had slight signs of sewage load, but were generally undisturbed by sewage (α-oligosaprobic). The impact of sewage was evident in the harbour areas, where the water was polluted (β-mesosaprobic). The western bay areas were classified as undisturbed (β-oligosaprobic) (Witting 1923).

After the committee's report had been published, the City Council made an ambitious master plan at the end of the 1920s to build a complete wastewater purification system to treat all wastewater generated in the city (Laakkonen 2001).

The changing role of research in the 1930s

The role of shore water research changed in the 1930s. The first large activated sludge plant was completed in 1932 and its new laboratory monitored the effectiveness of the treatment processes. However, as it was considered necessary also to monitor the recipient waters, in 1932 and in 1936 the Department of Public Works funded physico-chemical and hygienic studies under the control of the Laboratory of Sanitary Studies.

Välikangas and Häyrén were appointed to investigate the state of the sea area of Helsinki and to estimate the need for monitoring. In 1932–1933 Välikangas analysed the plankton samples, while Häyrén investigated the shore vegetation as described earlier (Häyrén 1933, Välikangas 1933). The physico-chemical parameters measured included oxygen, ammonium and permanganate. The sampling area and methods were almost the same as in 1919–1920, but samples were taken only once, in August. The purpose of the studies was to compare the results and draw conclusions.

Their studies showed that the state of the sea area was almost unchanged as compared with that presented in the previous results, and only minor local changes had occurred depending on the location of the sewage outlets. Välikangas did not foresee any drastic changes. He recommended monitoring studies every five years and saw no need for annual monitoring (Välikangas 1933).

In 1936 the second large treatment plant using activated sludge method was completed and the Department of Public Works asked the same researchers to determine whether any changes had taken place. The study area was limited as compared with that in the earlier studies, with the sampling sites being located in the most polluted inner bay areas and on the western side placed around the newly built sewage treatment plant. Samples were collected five times, two of them in November 1936 (Välikangas 1936, Häyrén 1937).

Välikangas and Häyrén made the new study and their methods were almost the same as those used earlier, except that the Utermöhl technique and an inverted microscope were used for the first time in plankton research. The eastern area was classified as polluted (β-mesosaprobic). The western bay area was only slightly disturbed, mostly near the outlet from the wastewater treatment plant. Välikangas concluded that the plant was malfunctioning (Välikangas 1936).

For the first time, the scope of their research included a study of the bottom fauna. This work was done by Välikangas, Heikki Järnefelt, who was appointed as the first professor of limnology in 1939, and Erkki Halme. The chemical content of the sediment was analysed in the Research Laboratory of Agricultural Chemistry. The results showed a widespread lack of oxygen, and in most places no bottom fauna was found; the bottoms of the inner bays were practically dead. As sediment analysis had confirmed the presence of large amounts of nitrogen and phosphorus, the researchers suggested that the innermost bay could be restored by attempting to exhaust the nutrient stock of the sediments by increased water exchange (Välikangas 1936). Observations were also made of repeated fish kills in the inner bays in the 1930s (Järvi 1938).

In 1938 Välikangas and the Laboratory of Sanitary Studies made an integrated study of nine swimming places. Their bacteriological, physico-chemical and planktological data showed that the water was more or less polluted at most of the swimming locations. Swimming was to be avoided entirely at one place, and only on an island south of the cape of Helsinki was the water found to be almost clean (Välikangas 1938).

The post-war period

In 1939–1945 hardly any water samples were collected or analysed due to the Second World War. But the war also had other more long-lasting impacts on science. Above all, the biological research tradition that had been strong in the pre-war era now came to an end, even though some plankton samples were collected by Välikangas in the 1940s and the 1950s (Archives of the Finnish Institute for Marine Research).

After the war, the area of the city quintupled, but pollution studies were now being done by only one researcher, Harry Cajander, who had studied chemistry at the Helsinki University of Technology. After the war Cajander started to work at the laboratory of the Department of Public Works that was operating in a wastewater treatment plant complex. In 1947 Cajander started to study shore waters and collected altogether 140 water samples. He stated in his annual report that the monitoring of the recipients should be increased and that the laboratory desperately needed more staff (Vuosikertomus puhdistuslaitoksen toiminnasta vuonna 1947). Indeed, next year a laboratory assistant was hired and the sampling gradually expanded, being the most extensive in 1954, when more than 2000 water samples were taken.

At the beginning Cajander's main aim was to have an overview of the pollution situation around the year. Measurements of temperature, transparency (max. 2 metres), turbidity, oxygen, and pH were made. New studies included measurements of BOD_5. He recorded the presence of plankton blooms, oil and rubbish at the sites. Although Cajander repeatedly reminded the Board of Public Works of the need for biological research to determine the water quality, no biological research was done (Vuosikertomus puhdistuslaitoksen toiminnasta vuonna 1950, 1951). He acknowledged the need for long-term data and published his results in a book that documented the changes that had taken place in 1947–1962 (Cajander 1965). The book contains a detailed description of each sampling area in the post-war period.

Cajander did not use a classification system, but he prepared one map on the pollution situation of the sea area of Helsinki for the first national committee studying water pollution in the late 1950s. The most polluted areas were the harbours and areas close to sewage outlets, but some undisturbed areas were also found in the recently annexed outskirts of Helsinki (Cajander 1959).

At the beginning of the 1950s Erkki Halme and Seppo Hurme studied the state of fish stocks and fisheries in the coastal area off Helsinki with funding provided by the City of Helsinki. They evaluated the water quality on the basis of physico-chemical parameters (temperature, salinity, oxygen, potassium permanganate consumption, colloids) and compared their results with those of Välikangas from 1919–1920. These comparisons showed that the pollution situation had remained relatively unchanged (Halme and Hurme 1952).

In 1947, the Laboratory of Sanitary Studies started hygienic monitoring of the water quality of swimming locations regularly, and in 1958 with standardised methods using faecal coliform bacteria and faecal streptococci indicators (Gorbatow and Pönkä 1986).

Marine pollution studies in the early 1960s

At the request of the City of Helsinki, the Finnish Institute for Marine Research made studies on the pollution of the urban sea area in 1961–1962 (Merentutkimuslaitos 1961, 1962). During one week in 1961 samples were collected at 104 sites, most of them in the western bay areas, and six at the outer archipelago. Salinity, temperature, pH, turbidity, colour, oxygen and ammonia were studied. The new parameters measured were inorganic phosphorus, nitrates, nitrites and silicates. *E. coli* bacteria were studied by the municipal laboratory. Bottom fauna were also studied. A classification system based on physico-chemical and bacteriological parameters was applied (Merentutkimuslaitos 1961). In the following years the study was repeated.

The National Water Conservation Laboratory made a rather similar study in 1962–1964 (Säntti 1965) that was regarded as broadly significant from the perspective of finding measures for the protection of coastal waters. Most of the samples from 40 sites were collected in late winter after the ice had melted, with each site being sampled 1–9 times. Most of the sites were located in the western bay areas. Temperature, oxygen content, chlorides, pH, permanganate, BOD_5, and *E. coli* bacteria were measured, along with some new parameters: conductivity, total phosphorus and nitrogen. This study, which was carried out by a governmental institution, was apparently the first one that was made independently of the municipality in order to corroborate the findings of municipal studies. Government corroboration of municipal monitoring has continued on an annual basis.

Monitoring from 1966 to the present

A new Water Act addressing water protection entered into force in 1962. In 1964, the City of Helsinki appointed a new committee to find solutions to the marine pollution problems being caused by sewage. The committee initiated technical and hydrobiological studies in late autumn 1964. The focus was on the western bay areas, where the pollution situation had become critical due to increasing wastewater loadings. The aim was to develop monitoring methodology and provide basic facts on the eutrophication and the role of nutrients, especially phosphorus, in order to facilitate effective wastewater management in the future. Water exchange and dilution were studied, nutrients measured, and bottom fauna and sediments examined. Primary production measurements were also initiated. Unfortunately, this preliminary phase produced only a few results, due to malfunctions or lack of proper equipment (Selostus Helsingin kaupungin merivesitutkimuksista ajalta 1.X.1964–30.IX.1965).

The old laboratory of a wastewater treatment plant became the Water Conservation Laboratory of the City of Helsinki (since 1993 Environment Centre of the City of Helsinki). The number of staff increased during the 1960s from a few researchers to over 50, including engineers, chemists, limnologists and biologists. The municipal authorities issued annual reports as well as reports on special subjects (e.g. Melvasalo 1971,Viljamaa 1972, Eerola 1979). Phosphorus measurements were initiated at the end of the 1960s and α-chlorophyll measurements at the beginning of the 1970s. The regular annual monitoring started in 1966. The monitored area expanded and the number of samples increased, but became gradually also routine activity of the laboratory. The focus of the studies shifted from the shoreline to the seaside, especially after the introduction of the sea outlet in 1986. In the 1990s the number of regular sampling points was reduced, but due to algal blooms biological studies on plankton were intensified (Pesonen *et al*. 1995, Pesonen 2000, Autio *et al*. 2003).

Since the 1970s a national classification system has been used to rate the quality of surface waters; (excellent, good, satisfactory, passable, poor). The mean values of three successive years of the following parameters are taken into consideration: oxygen saturation range, transparency, turbidity, thermotolerant coliform bacteria, α-chlorophyll, and total phosphorus. As the new EU directives emphasize the use of biological data for classification, a new classification system is under development.

The municipal continuum

The urban sea area has always been a focus of attention. As increasing pollution has continued to affect the interests of several stakeholders, various municipal, governmental and private institutions might have had cause and means to launch scientific studies of the water quality, at least in principle. In practice, however, the municipality, i.e. the City of Helsinki, was the sole initiator of pollution studies for most of the 20th century. The main reason for this is that the City Council had the political will to provide economic support for the studies, and the municipal departments and laboratories had the personnel and skills needed to conduct scientific examinations. The results of these studies were eventually used in order to formulate municipal water protection policy. On this basis the long history of scientific studies on marine pollution can be defined as a municipal continuum.

The methodological basis of municipal pollution studies in the Helsinki area has been surprisingly extensive since 1904 (Table 1). Almost since the very beginning, physical, chemical, hygienic and biological methods were adopted. The municipal laboratories have overseen and conducted most physico-chemical and bacteriological studies on pollution of urban watercourses since 1904, with annual monitoring in the form of regular sampling starting in 1947. More or less regular biological monitoring of water bodies started in the 1920s and 1930s. Statutory monitoring, involving the use of hygienic, physico-chemical and biological methods, was initiated in 1966. The number of samples taken annually did not increase substantially until the 1960s, while in the 1990s the number of samples decreased slightly (Figs. 3–5). The data in Fig. 3 are only indicative, because exact data are not available. In addition, the period of statutory monitoring needs a study of its own.

The City of Helsinki has cooperated primarily with the University of Helsinki and secondarily with the Helsinki University of Technology (previously Helsinki Polytechnic Institute) to develop the skills and manpower required in biological and practical pollution studies. Impacts of pollution, especially blue-green algal blooms, raised scientific interest among the biologists of the University of Helsinki, resulting that several scientific papers were published on the pollution of the sea area off Helsinki prior to the Second World War.

Several clear differences in water quality research policy can be seen during the 60 years prior to the introduction of statutory monitoring in Helsinki. Before the Second World War the sea area was effectively studied by eminent scientists holding doctoral degrees, and their research was supported by adequate funding. Their results were made available to policy makers and the general public, as well as to the scientific community.

The Second World War changed this. It seems that due to the post-war economic hardships in Finland, the municipality was not able to carry out new multidisciplinary research programmes. The result was the breakdown of the means of transmitting research methods from one generation to another and from one field to another. In the post-war period, water quality and wastewater problems were of minor interest until the mid-1950s, when municipal environmental politics re-emerged. In addition, the Water Act of 1962 obliged the municipalities to purify the wastewaters and to monitor water quality on a regular basis. During the 1960s many resources were invested in the preparation of extensive annual quantitative studies. However, the statutory monitoring gradually became more bureaucratic, and the focus of the studies shifted from the shoreline to the seaside in the 1990s, after the introduction of the sea outlet. More samplings were conducted further away from the shores and hence also further away from the urban population.

Despite findings that the quality of the water off the shores of Helsinki has been poor since 1908, there is evidence that there were also some undisturbed surroundings and clean shores prior to the 1960s. Until the 1960s, in Helsinki the main objective was to study hygienic and organic pollution, thereafter the focus has been on eutrophication. Classification systems were used as tools to assist the public and decision-makers in interpreting the scientific findings. The system used to measure and classify physico-chemical parameters was based on ammonium values and oxygen demand. Biological studies had an important role in demonstrating the influence of wastewaters on the aquatic environment.

Table 1. Physico-chemical, bacteriological and biological parameters used in the water quality research in Helsinki in 1904–2003. + method used, * experimental use. Sources: Bergman 1908, Witting 1923, Välikangas 1936, Cajander 1965, Pesonen 1971, Enqvist 1974, Autio *et al*. 2003.

Parameters	1904	1908	1919	1936	1950s	1966–2003
Temperature	+	+	+	+	+	+
Transparency	+	+			+	+
Colour	+	+				+
Salinity	+	+	+	+	+	+
pH				+	+	+
Oxygen		+	+	+	+	+
NH_4		+	+	+	+	+
NO_2, NO_3		+	+			
Total N						+
Total P						+
Coli bacteria		+			+	+
MnO_4, COD	+	+	+	+		+
BOD_5		*	*	*	+	+
Biological parameters		+	+	+		+

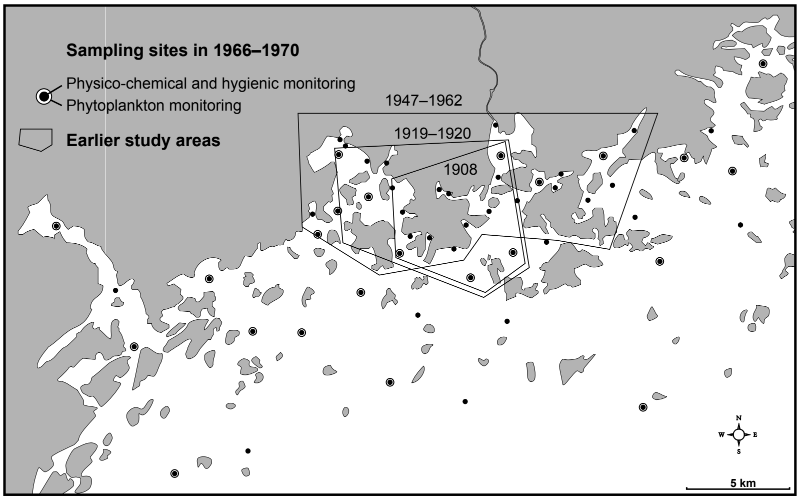

Fig. 3. Study areas in 1908, 1919–1920, 1947–1962, and sampling sites of statutory monitoring in 1966–1970. The study area expanded manyfolded due to the expansion of administrative area of Helsinki in 1946, and in the 1960s when Helsinki and Espoo, its nearby city, launched their common statutory monitoring. Source: Bergman 1908, Witting 1923, Cajander 1965, Pesonen 1971.

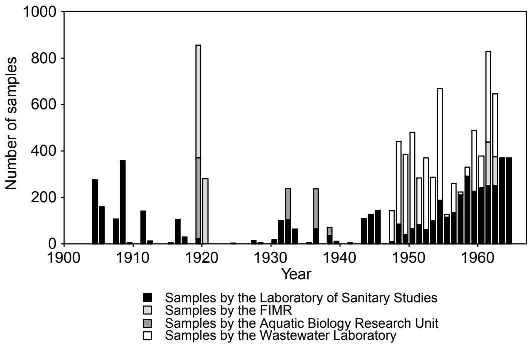

Fig. 4. Number of samples taken annually by different organisations in Helsinki in 1904–1965. Sources: Archives of the Laboratory of Sanitary Studies, Bergman 1908, Witting 1923, Välikangas 1936, Cajander 1965, Selostus Helsingin merivesitutkimuksista ajalta 1.10.1964–30.9.1965, 1966–1969, Pesonen 1971.

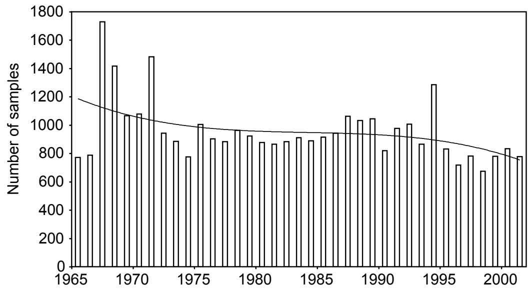

Fig. 5. Number of physico-chemical and hygienic samples collected in 1966–2002 for the statutory monitoring of the sea area off Helsinki. Source: Environment Centre of the City of Helsinki.

Indicator species of macrophytes and plankton species were used for saprobic classification. The years 1904–1908 and 1947–1960 were the only periods in which no classification system was applied.

The role of the municipality has been crucial in the development of environmental sciences. This study shows that a number of basic methods and theories used today were introduced already a century ago and rapidly modified for local conditions. Although Helsinki was a small and relatively poor city suffering from pollution in the beginning of the 20th century, the municipality was able to find solutions through scientific research. Then again, it is obvious that the quantity, variety, accuracy and comparability of the methods have in general improved. However, the question of the development of scientific methods is more philosophical than practical, because society and science are in constant dialogue. The transformation of the urban society and environment has been so profound in the past century that there is no point in attempting to evaluate the quality of studies from a normative point of view. Therefore, instead of claiming that the quality of scientific methods has increased or decreased, it may be more appropriate to conclude that science has changed in accordance with society and its perceptions of its environment, and it will continue to do so in the future.

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