Evaluation of the ReVAQ project to achieve safe use of wastewater sludge in agriculture

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Abstract The use of wastewater sludge on arable land in Sweden has been limited for some years due to the low quality, in some respects, of the sludge and to the reluctance of farmers and the food industry to use it. To improve the quality of the sludge, the ReVAQ project has been started, and it now involves seven municipal wastewater organisations. The goal of the project is to introduce a process in which the quality is successively improved by a series of actions taken by society. These actions include tracking and eliminating sources of heavy metals and other substances. As there are numerous sources of some of the substances, the work concentrates on the major sources. Another important activity is to provide information to the users of the wastewater system. The project is being evaluated by Urban Water AB. The results from the first two years indicate that it may be possible to reach the primary technical goal: to obtain a sludge quality that corresponds to that of household wastewater. The more ambitious goal of reaching a quality corresponding to that of WC water (the sum of urine and faeces) does not seem realistic without far-reaching changes in society. The organisations involved, which take the work seriously and are goal-oriented, have achieved measurable results in a short time. The work is also accepted and supported by the board members. More effort is needed, however, to inform the users about the system, and to [motivate them to] change their behaviour regarding matters such as the purchase of everyday products and the use of the toilet facilities.
Keywords Nutrients; recycling; sludge; sources; sustainable; urban water; wastewater

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Introduction

The ReVAQ project aims to achieve safe and sustainable recycling of the nutrients in sewage sludge to agriculture. The project, carried out by seven Swedish municipal wastewater organisations, will take three years, probably with a time extension if it is successful. The name ReVAQ is a Swedish acronym that can be translated as 'clean fertilizer from sewage'.

The purpose is to successively decrease the content of hazardous substances in the sludge so that the quality is suited for use in agriculture. The concentrations in the sludge from most Swedish municipalities of the substances studied are today below or well below the current national and international limits for spreading on farmland. Even so, there are restrictions in Sweden for the spreading of sludge on farmland, initiated by the Swedish food industry, mainly for marketing reasons. Organisations that fulfil the requirements of the ReVAQ project are allowed to spread sludge on farmland, with the usual precautions that are prescribed by SEPA (Swedish Environmental Protection Agency).

The work in the municipal organisations aims to decrease the production and use of hazardous substances in society, or at least to reduce the flow of these substances to the wastewater system. The focus is on heavy metals, but some hazardous organic substances are also being studied. The project aims to reach levels of heavy metals in the sludge which correspond to those found in household wastewater. An even higher goal to strive for is that the metal content in the wastewater sludge shall correspond to that of WC water (the sum of urine and faeces), thereby approaching, in relation to the concentration

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of phosphorus, the quality of food. The goals for hazardous, anthropogenic organic substances and for pathogens are that they shall not be detectable.

The project also aims to influence the understanding and attitudes at the municipal administrations involved, and to influence all of the users of the wastewater system, households and industry.

In the long run, the goal is to achieve a quality of sludge that makes the use of it on arable land accepted and sustainable. In the short run the goal is to initiate and establish a process for quality improvements that is clear, purposeful and accepted.

Regular sampling and analysis of the wastewater and the sludge is conducted for all relevant physico-chemical parameters including heavy metals. Measurements and tracing investigations are made upstream from the treatment plant, to quantify the contributions from all possible sources. This is done partly by structured measurements in the sewer network, working from the plant and upstream, and partly by sampling and analysing the contribution from selected sources, such as households, dentists, photo laboratories and some industries.

Mass balances are developed for each of the substances studied, showing the contribution from each source to the content in sludge. Sometimes these mass balances do not match: there are still some substances from unknown sources. An example of a mass balance for one of the organisations is shown in Table 1.

The household figure includes WC water and total grey water (baths, dishes and laundry). The household figure also includes artist paints, as these may contain high quantities of cadmium.

The sludge from six of the organisations has been analysed for some hazardous organic substances: brominated flame retardants (HBCD and PBDE), linear alkylbenzene sulphonates (LAS), phthalates (DEHP), and triclosane. Only two samples have been taken for each of the six organisations, and the data does not yet permit any conclusions, although there seems to be a seasonal variation.

There is a strict quality control for the use of sludge on arable land. For each section of land where sludge is to be used, the soil is analysed for its content of phosphorus and heavy metals. The concentration of phosphorus in relation to some heavy metals determines how much sludge, if any at all, may be spread. A national norm regulates these requirements. The spreading of sludge is allowed only for certain crops (mainly fodder crops) and at certain times of the year. A careful record of each spreading is kept. The crop is also analysed for its content of heavy metals, e.g. the content of heavy metals in the grain.

Pathogens are checked by analysing for salmonella in the sludge.

One of the most important activities is to inform the users about the wastewater system. In one of the municipalities there are annual campaigns in the subways, informing

Table 1 Sources of cadmium reaching the Bromma Wastewater Treatment Plant in 2004

Source	g/year
Households, grey water	1140
Households, from food	1040
Households, unknown	1250
Stormwater	550
Drainage water	350
Car washes	440
Drinking water	100
Industry	60
Chemicals in the STP*	30
Unknown	730
Total	5690

*Sewage Treatment Plant

people of what may and may not be thrown into toilets. In another municipality a video has been produced and shown to the customers on TV in supermarkets. There are frequent visits by school classes to all of the treatment plants. Information campaigns are also directed to selected groups, such as artists who paint (regarding cadmium in artist paint), copying and printing shops (regarding silver), car washes (regarding cadmium, zinc and other metals) and dentists (regarding mercury).

Parallel to the information campaigns, actual remediation work of different kinds is carried out in all of the municipalities. Examples include the cleaning of drains and pipes from dental offices, both in the buildings and in the wastewater system.

Although similar efforts are done in several Swedish municipalities, the ReVAQ project has received high credibility, due to the outspoken focus, collaboration with the food production sector through the steering committee and through independent certification/control of processes and measurements by the accredited quality control institute SP.

The project ReVAQ has a steering group that monitors the results, gives advice when needed and selects new project members (which must fulfil specified requirements regarding both the quality of the sludge and organisation). The steering group includes representatives from the ReVAQ municipalities, the food industry (Cerealia), the farmers organisation (LRF), the Swedish Society for Nature Conservation (SNF) and the Swedish Water and Sewage Works' Association (Svenskt Vatten). The quality of the processes and measurements is checked by the accredited Swedish quality control institute SP.

Evaluation of aim and methods

The company CIT Urban Water Management AB (UWAB) is based on the results of research encompassed by the six-year MISTRA research programme, Urban Water, which is an inter-disciplinary research programme conducted at eight Swedish universities, involving 15 Ph.D. students. The UWAB company was asked to evaluate the ReVAQ project, and to answer the following basic questions.

- Is the use of sewage sludge on arable land in accordance with the Swedish national environmental goals, as well as the goals suggested by SEPA, for recycling of phosphorus?
- Can it be expected that future development would make it possible to fulfil the requirements? To what extent can this be done (regarding concentrations of hazardous substances in the sludge)?

The aspects evaluated include:

- Actual improvements in the quality of the sludge;
- Attitudes of the governing board and the staff at the wastewater organisations towards the ReVAQ work; and
- Attitudes of the users of the system, such as households and industries, and of farmers and the food industry.

The evaluation of the ReVAQ project is being made by a group of researchers and consultants covering the environmental, technical and social sectors. Four of the seven participating organisations are included in the evaluation, which is based on the conceptual framework used by the Urban Water Programme, see Figure 1. The first phase of the assessment has concentrated on the environment, economy, technical function, and organisation and communication (socio-culture).

The project is being evaluated by:

- A critical reading of the annual reports submitted;
- Interviewing the staff and boards of the wastewater organisations, farmers, the food industry, and residents; and
- Visiting the four organisations selected, holding discussions with the management and the staff, and visiting the sludge treatment units.

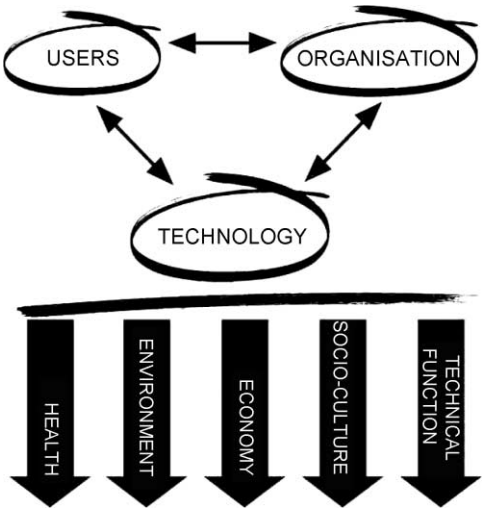

Figure 1 The Urban Water conceptual framework, defining the three subsystems and the five aspects of sustainability

Results and discussion

The four organisations studied all fulfil the current heavy metals requirements for spreading sludge on arable land. Measurements are required, however, to reach the future goals suggested by SEPA. All four organisations are making a considerable effort to reduce the flow of metals into the wastewater treatment plants. It is reasonable to believe that the metal concentrations can be further reduced in the future, and possibly even to reach the goal that the quality of the sludge corresponds to that of household wastewater. For some metals, e.g. lead and chrome, it is very difficult and will take a long time to reach the goal that the quality of the sludge (metal concentrations in relation to phosphorus concentrations) should correspond to that of WC water (i.e. only urine and wastewater).

Three examples of metal concentrations per kg of phosphorus in sludge for two years, 2003 and 2004, are shown in Figures 2–4. The concentration limits for 2005 (according to SEPA, see Table 2) are shown as a line. All three metals are well below the limit.

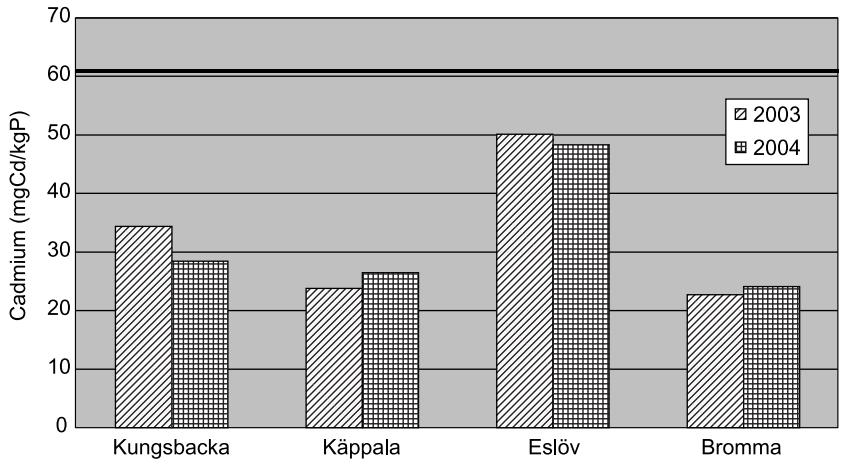

Figure 2 Concentration of cadmium per kg of phosphorus in sludge, 2003–2004, at the four ReVAQ organisations. The line shows concentration limit for 2005 according to SEPA

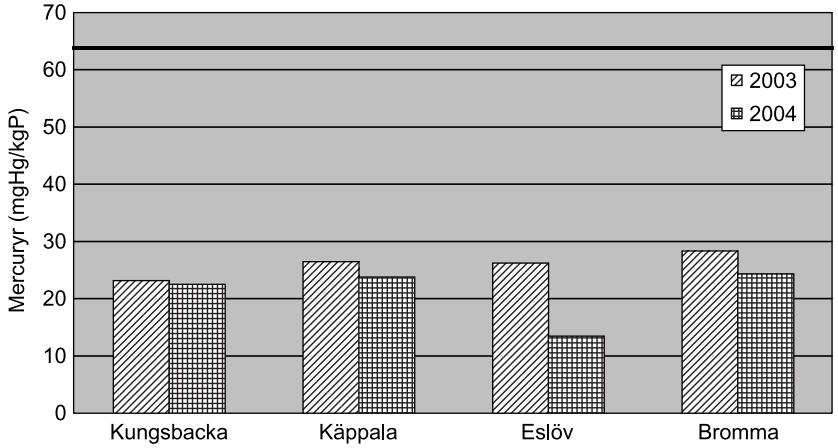

Figure 3 Concentration of mercury per kg of phosphorus in sludge, 2003–2004, at the four ReVAQ organisations. The line shows concentration limit for 2005 according to SEPA

Cost efficiency

The actual costs for sludge handling were around 30 euros per tonne of wet sludge (12 Euros for transport and spreading, 3 euros for administration of the ReVAQ project, and 15 Euros for the internal work by the staff). The internal cost for working on the ReVAQ project was somewhat difficult to estimate. Normally, the ReVAQ work was done by the regular staff, and very few or no additional people were hired. Some of the actions would no doubt have been taken anyway. However, in times when organisations are under constant pressure for cost efficiency, the ReVAQ work implies that the group of people working with environmental and preventive matters were not under the same pressure as the administrative staff or operational staff. The management apparently accepted the activities of the ReVAQ project.

The work to constantly improve the quality of the sludge also involves preventive and informative measures in society, i.e. actions that improve the environment at large. This means that fewer hazardous substances reach the wastewater treatment plant, which also

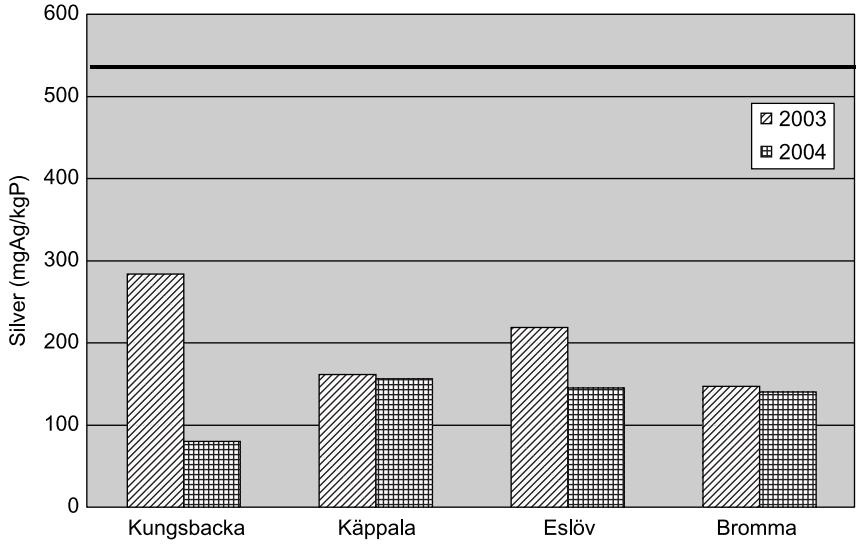

Figure 4 Concentration of silver per kg of phosphorus in sludge, 2003–2004, at the four ReVAQ organisations. The line shows concentration limit for 2005 according to SEPA

Table 2 Suggested limit values for metals to agricultural land, and the concentration in soil. Swedish Environmental Protection Board (2002)

		Limit concentration in wastewater (mg/kg DS*)	Limit concentration in wastewater (mg/kg P)	Max spreading to farmland (g/ha, year)	Limit concentration in soil (mg/kg DS*)
Cadmium	2005	1.7	61	0.75	0.4
	2010			0.55	
	2015			0.45	
	2020			0.35	
Mercury	2005	1.8	64	1	0.3
Silver	2005	15	540	8	–

*Dry solids

improves the quality of the discharged water (since a considerable part of the substances are water-soluble).

The alternative to using the sludge in agriculture has usually been to use it for the production of soil, for example by mixing it with sand and peat. This soil was then used for construction sites, golf courses, and for covering old solid waste deposits. The cost of soil production is also around 30 Euros, which makes the choice between agricultural use and soil production cost neutral.

Organisation and communication

The aim of this part of the evaluation was to investigate both the attitudes of the staff at the wastewater organisations towards the ReVAQ work, and how they handled their work in practice. The aim also included investigation of the attitudes of the management and the governing boards.

The staff and the board members at two of the wastewater organisations were interviewed about their attitudes to sludge being used as fertilizer and their roles in the ReVAQ work. The interviews showed that the staff and the board members held similar views on the importance of improving the quality of the sludge so that it can be used as fertilizer in agriculture. The extra cost for the ReVAQ work was considered to be reasonable and justified. The staff and the board members were aware that their efforts might lead to the result that the sludge cannot be used as fertiliser anyway. The reason for this is that the farmers and the food industry are market driven; they depend on the attitudes of the consumers.

The persons interviewed also expressed a wish that the ReVAQ project be prolonged or even made permanent in a formal way, since the preventive environmental work is important not only for the quality of the sludge but also to society as a whole.

The residents and enterprises that were interviewed showed less interest in the project and had not changed their behaviour much. This shows the difficulties of reaching people with environmental information, at a time when they are flooded with advertisements of all kinds. Greater efforts by the ReVAQ project to reach residents and small enterprises are a necessary part of attaining the goals.

Conclusions

It may be concluded that the ReVAQ project is a very important tool for the wastewater organisations (and society at large) in their preventive environmental work. By decreasing the use of hazardous substances, the flows of these substances to the environment in general are also decreased, which means that discharges to the receiving water, to soil and to the wastewater sludge are reduced.

The ReVAQ goal to reach levels of heavy metals in sludge that correspond to those of the household wastewater may be possible to reach. The goal of reaching levels that correspond to those of the WC water (near food quality) seems very difficult to reach without taking extreme measures in society.

The wastewater organisations take the work very seriously and are goal-oriented, which is highly commendable. Their efforts to inform consumers and small enterprise should be strengthened.

The work is cost effective, in the sense that the cost for all of the ReVAQ activities (per ton of sludge) equals the cost of using the sludge for soil production. The ReVAQ work is beneficial not only for improving the quality of the sludge but also for the environment as a whole.

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