

## **COMPARISON OF DIFFERENT OPTIONS FOR SEWAGE SLUDGE DISPOSAL USING MULTICRITERIA ANALYSIS AND LIFE CYCLE ASSESSMENT**

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### **ABSTRACT**

In this study several disposal options for sewage sludge are compared. Among others mono-incineration, co-incineration in a municipal incineration plant, incineration in the cement industry, gasification, wet oxidation, co-fermentation and application in agricultural are investigated. The systems include the whole wastewater and sewage sludge treatment and refer to 1 population equivalent (PE, 80 g COD/d). The evaluation of the options takes account of environmental, economic and social criteria with standardized cost-benefit scores. Disposal in a cement plant and mono-burning of the sludge with further treatment to recycle phosphorous are more favorable compared to the other scenarios investigated.

### **INTRODUCTION**

A Swiss sludge operator operates a sludge incinerator which is in need of replacement. To enable a future-proof system decision to be reached, various disposal routes had to be examined, innovative in some cases (Bättig et al., 2011). Tab. 1 shows the options identified for analysis. Important questions arise: Should a plant for recycling of phosphorus from the sludge ash be operated in the future? Should more innovative sludge treatment and recycling processes be included in the technical evaluation? Is direct recycling of phosphorus and nitrogen an issue for the long term? Are the results applicable to other treatment plants? The options were compared by means of an extended cost-benefit analysis called multicriteria analysis. The evaluation of the options takes account of environmental, economic and social criteria with standardised cost-benefit scores.

### **METHODS**

The evaluation of the options is conducted with a multicriteria analysis which takes account of environmental, economic and social criteria with standardised cost-benefit scores (Bättig, Dettli, Klingler, Frischknecht, & Tuchschnid, 2008). All options include the whole wastewater and sewage sludge treatment and refer to 1 population equivalent (PE, 80 g COD/d).

Data were collected with extensive questionnaires directly from the sludge operator. Data were provided for energy and material consumption, wastewater and sewage sludge constitution, monoburning ash constitution as well as production of products such as biogas,

electricity, and heat. The phosphorous recycling and wet oxidation operation data are collected with questionnaires from two plant operators. Other data stem from literature and expert estimates. Ecoinvent v2.2 (ecoinvent Centre, 2010) is used as background database.

The options produce different products such as biogas, electricity, heat, phosphorous and fertilizer. These products are taken into account by credits as they compete with products from conventional production such as natural gas. The credits are composed of costs and environmental impacts of conventional production.

The basis for evaluation of the environmental impact is a life cycle assessment for each option. Because sludge is characteristically a highly nutrient-rich waste product, the following criteria were selected and weighted by a group of experts: Conservation of non-renewable energy sources, conservation of non-renewable resources, climate change, diffusion of hormonally active substances, eutrophication, human toxicity, ecotoxicity, and highly radioactive waste volumes. In terms of economics, the disposal costs and security criteria and the financial risk were evaluated. In social terms, local acceptance (odour, noise), acceptance by society and security of supply were evaluated. Criteria-related quantitative indicators (loads, costs) or qualitative indicators (expert estimates) were used.

A cost-benefit score is determined for every criterion and summarized to one final score. The final score is in the range of 0 (no benefit) and 1 (highest benefit).

Tab. 1: Description of options investigated

| No. | Description   | Sub-option |                             |
|-----|---|------------|-----------------------------|
| 1.1 | WWTP as existing, mono-incineration on the WWTP site  | 1.1.a      | Immediate P recycling       |
|     |   | 1.1.b      | Monofill, P recycling later |
| 1.2 | Co-incineration in a new CHP plant at the site of the LUerne waste incineration plant                     | 1.2.a      | Immediate P recycling       |
|     |   | 1.2.b      | Monofill, P recycling later |
| 2   | WWTP without digestion, mono-incineration on the WWTP site  | 2.a        | Immediate P recycling       |
|     |   | 2.b        | Monofill, P recycling later |
| 3   | Co-incineration of sludge in a waste incineration plant   | -          | -                           |
| 4   | Sludge incineration in the cement industry  | 4.a        | Sludge drying at WWTP       |
|     |   | 4.b        | Drying at cement works      |
| 5   | Sludge gasification at the WWTP   | 5.a        | Immediate P recycling       |
|     |   | 5.b        | Monofill, P recycling later |
| 6   | Wet oxidation at the WWTP   | 6.a        | Immediate P recycling       |
|     |   | 6.b        | Monofill, P recycling later |
| 7   | External anaerobic digestion at an existing plant with agricultural substrate, application in agriculture | -          | -                           |
| 8   | Application of the sludge from the WWTP in agriculture  | -          | -                           |

## RESULTS

The results of the multicriteria analysis are shown in Fig. 1. The option with drying and disposal in the cement industry (4b) achieves the highest cost-benefit score. The critical dimensions are the environment (energy efficient process, resources and energy sources are substituted) and the economics (low acceptance prices).

The "mono-incineration" options (1.1a – with immediate phosphorous recycling, 1.1b current situation, ash in monofill, phosphorous recycling follows later) are only slightly behind option 4b. Their advantages are the good economics and reliability of the process and the high social

acceptance. Phosphorous recycling from the monofilled ash will then follow when it becomes economic as phosphorus prices rise.

The technically innovative processes "wet oxidation" (option 6) and "sludge gasification" (option 5) lag well behind. The reasons are the relatively low benefit for the environment and the high costs of these processes.

The options with immediate phosphorus recycling generally have lower cost-benefit scores than the corresponding options with monofill and later phosphorous recycling. This is because the environmental benefit is the same (it is not timing dependent), but a plant for phosphorous recycling performs less well in the "economics" dimension.

Because the timescale to be considered for this study is defined as 20 to 40 years, disposal routes with agricultural recycling were also examined, even though the use of sludge as an agricultural fertilizer has not been permitted since 2006 in Switzerland. Option 8 (direct application in agriculture) is in the top half of the options studied and achieved average scores for all three dimensions. Option 7 (external anaerobic digestion and application in agriculture) is ranked lower. In terms of the environment it should be mentioned that direct input of organic pollutants into the soil through sludge discharge could not be considered, whereas dissemination of hormonally active substances into the environment could.

A sensitivity analysis was carried out considering alternate weighting factor for all criteria, optimal energy efficiency, application of the method of ecological scarcity (Frischknecht, Steiner, & Jungbluth, 2009) instead of the environmental indicators mentioned above, considering "new technologies" as "established technologies" and high price for phosphorous fertilizers. The sensitivity analysis carried out showed that the evaluation obtained is quite robust, even with different assumptions.

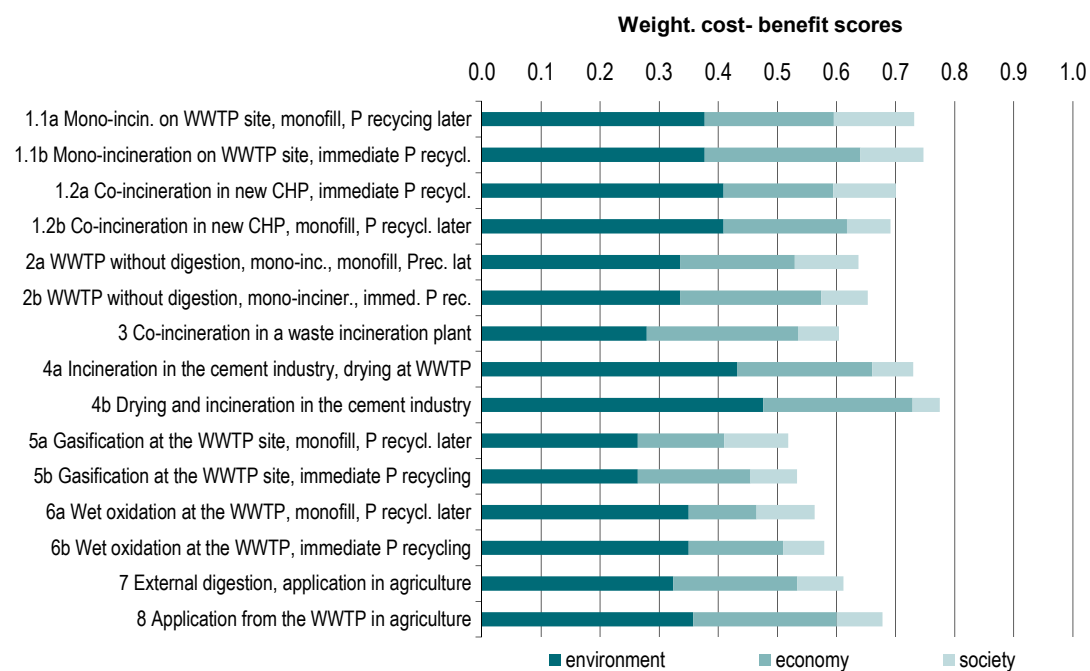


Fig. 1: Results of the multicriteria analysis.



## CONCLUSIONS

To conclude, the study showed that mono-incineration is a suitable and future-proof process for sludge disposal. But also recycling at a cement works is an equivalent alternative. Furthermore, a plant for phosphorus recycling is not indicated for the time being. The sludge ash should be deposited in a monofill so that phosphorous recycling at a later date can be ensured. The study also showed that investment in sludge gasification or wet oxidation is not recommended from today's perspective.

The results obtained are guaranteed to be transferable to other treatment plants in Switzerland because sludge treatment and disposal are largely independent of the location. Some differences occur due to varying transport distances, potential for district heat output and the plants already in existence.

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