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> Phosphorus flows in Switzerland

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> Summary

Introduction

Phosphorus is a principal element in the nutritional chain of all organisms, and cannot be substituted. Owing to this, prognoses according to which the static availability of the easily accessible ground resources of phosphorus amounts only to several decades or several centuries (50–330 years) appear alarming. However, an availability of several centuries is only achieved if the lower- quality resources of phosphorus contaminated with heavy metals and/or subject to higher mining costs are included. In Switzerland, over and above the increasing global scarcity of phosphorus resources, phosphorus is often regarded simply as a pollutant in surface waters, since it has played a major role in the eutrophication of many lakes. Although the inputs to surface waters have been substantially reduced over the past 20 years, a potential still remains for local input reductions.

From these two standpoints – scarcity and eutrophication – countries without their own resources of phosphorus, coupled with intensive use of the land, as in agriculture, as for example in Switzerland, there is intense interest in gaining a knowledge of how the phosphorus cycle is now structured, and how it could be optimised. Despite the numerous studies carried out on the use of goods containing phosphorus in Switzerland, an overall perspective from the standpoint of resource utilisation that could permit the establishment of options for the optimisation of the phosphorus cycle has been lacking.

In the present study, values for phosphorus flows in Switzerland and the associated ranges of uncertainty have been quantified for the year 2006 in an analysis based on a substance flow simulation model having a resolution, data quality and consistency never before achieved. Using an error analysis, a simple scheme was used to identify the relevant flows subject to error and to validate them. Based on the results achieved, a more comprehensive understanding of the flow cycle than achieved in previous work was obtained. The present study fulfils (for the first time) the demand for a comprehensive study of the total phosphorus cycle in Switzerland. This represents an essential step enabling the potential for increasing material efficiency and reducing risks of the phosphorus cycle to be adequately assessed from a holistic standpoint.

Method

For the analysis of the phosphorus household in Switzerland, the method of substance flow analysis was applied. The phosphorus cycle was set up in agreement with the quantitative and qualitative importance of the individual processes that phosphorus undergoes in Switzerland. For this, the system boundary used in customs law was chosen. The system was quantified for the year 2006. The main system is subdivided into the following 6 interdependent subsystems:

a) *Agriculture animals* includes all processes needed for the production and provision of animal feeds;
b) *Agriculture plants* includes both the processes required for the production and provision of plant nutrients, and also the processes used in forestry and the manufacture of paper, building timber and energy products;
c) The *chemical industry* imports and processes cleaning products containing phosphorus, as well as chemicals for production;
d) *Household & trades* includes all processes in connection with the consumption of foods, products containing wood, and cleaning products. In addition, the private gardening sector is included;
e) *The waste* sector includes all processes associated with the disposal and the treatment of liquid and solid wastes; and
f) *Ground and surface waters* includes flowing surface waters, and the lakes, including their sediments.

Since the values for phosphorus flows are rarely available from the literature, these were generally calculated from the products of the substance flows and the phosphorus concentrations obtained from data research. The data sources mainly consist of statistical surveys and scientific publications, and, in cases where no other data were available, of own surveys, generalisations, rough extrapolations, or rough estimates of the parameters. All data were provided with a range of uncertainty. The required flows were determined based on the relative and absolute uncertainty and on the true value of the flow. An uncertainty of < 20 % was achieved for > 80 % of the flows.

Results

Switzerland is a net importer of phosphorus. An annual quantity of approx. 16 500 tonnes of phosphorus is imported, and approx. 4000 tonnes exported. Thus Switzerland is subject to a growth in the total quantity of phosphorus of approx. 12 500 tP/a. Exports arise mainly from agriculture (imports of feeds and mineral fertilisers) through flows abroad via ground and surface waters and the export of animal wastes. The greatest increase in the total quantity takes place in the subsystems *agriculture plants,* with an increase of approx. 3500 tP/a and the *waste* sector, with an increase of approx. 9000 tP/a.

Overall, the phosphorus cycle is dominated by the agriculture (farmyard manure, feeds) and disposal sectors, and, to a lesser extent, by the household and trades sectors. The sectors *chemical industry,* and *ground and surface waters* with < 2500 tP/a represent less significant distribution and accumulation processes.

In *agriculture*, the almost closed cycle between animal production and plant production includes the most significant flows within the Swiss system (farmyard manure and animal feeds, each with approx. 30 000 tP/a). Further, the imports of feeds and mineral fertilisers, with 5600 tP/a and 5900 tP/a respectively, play an important role in plant production. Green fertiliser from compost and fermentation, with a total of just under 1100 tP/a, are less significant for the total system.

The subsystem *household & trades* is a once-through process with an input of approx. 9700 tP/a, consisting of approx. 78 % foods, approx. 10 % cleaning products, approx. 9 % fertilisers, and < 3 % wood/paper. The goods consumed are consigned directly to the waste industry in the form of various waste substances, and represent over 70 % of the input to the waste sector (domestic waste water, refuse, green waste).

In the *waste sector*, an annual quantity of approx. 13 500 tP are processed. In 2006, a mere 13 % (approx. 1700 tP/a) were treated in Switzerland and employed either in agriculture or in private gardens. Approx. 1500 tP/a of animal wastes were exported abroad for reprocessing. Accordingly, phosphorus losses amount to > 10 000 tP/a (approx. 80 %). In this, by far the most important sinks in this subsystem are the landfills, with approx. 6300 tP/a, followed by the cement factories, with approx. 3000 tP/a.

On a quantity basis, the largest as yet unused potential for phosphorus recovery in the *waste sector* lies in the reprocessing and reuse of waste water and sewage sludge (approx. 5800 tP/a). In 2006, 43 % of the sewage sludges were consigned to monovalent sludge incineration and from there to bioactive landfills. A further 25 % were incinerated in the MWIP and 22 % in cement factories. The remaining 10 % were consigned at this time to agriculture. In addition, the system incurs losses of 1500 tP/a through the export of animal wastes.

Discussion and options for future action

From the point of view of resources, phosphorus management is not optimally organised in Switzerland, and is in need of improvement. Potential recycling paths, such as feeding of animal wastes or the use of sewage sludge as fertiliser, have been prohibited in recent years for reasons of hygiene and risks to the environment. However, it was largely possible to close the phosphorus cycle, enabling the import of mineral fertiliser to be reduced. The following four options for future action

a) Use of sewage sludge ash as fertiliser;
b) Use of animal meal as fertiliser;
c) Use of animal meal as animal feed;
d) Consequential recycling of green waste.

illustrate the substantial potential for closing the phosphorus cycle in Switzerland. With the option for future action using sewage sludge ash as fertiliser, the need for mineral fertiliser drops to 20 % based purely on a phosphorus balance; using animal meal as fertiliser, to 50 %; using consequential recycling of green waste, to 87 %. Using animal meal as feed reduces the import of feeds by 50 %. These figures indicate the potential for reducing the phosphorus requirement from a substance standpoint. When other factors such as fertiliser efficiency and feasibility are included, the potential using sewage sludge ash as fertiliser and animal meal as fertiliser, is 60 % lower in each case, and using consequential recycling of green waste, 40 % lower. Using a combination of these measures, and taking the above factors into account, a 50 % reduction of the import of mineral fertiliser can be achieved. In this, however, it must be taken into account that the increase in total phosphorus in agricultural soils would be doubled. It

is yet to be ascertained what consequences this would have from an environmental point of view.

The greatest potential for the optimisation of the phosphorus cycle in Switzerland lies in the management of sewage sludge. This sector represents the most effective control option for the BAFU. At present, there are 14 monovalent sewage sludge incineration plants in operation, whose ashes could not till now be employed as fertiliser. As a first step, the ashes of the existing plants could be separately deposited in a landfill site. This procedure would ensure that these could later be used as raw material in fertiliser production, as soon as technical processes for the manufacture of fertiliser from sewage sludge ashes are commercially mature. Furthermore, concerted financial or political support could accelerate the market introduction of these processes in Switzerland. In a further step, it could be ascertained whether animal wastes could be converted to fertilisers in the same treatment process. By contrast, giving priority to the separate collection of green waste in the whole of Switzerland seems less effective, since the remaining potential for this is only slight owing to the separate collections of green waste that have already been introduced by the municipalities.

Future perspectives

In optimising the phosphorus cycle, in addition to resource aspects, further aspects such as those discussed briefly in the present study must be considered. The following aspects are relevant in this connection: a) economical acceptability; b) social and political acceptance; c) technical and logistical implementation, and d) ecological aspects. By analysing these and other aspects, the question as to the measures needed at political level could be answered in order to achieve an optimised phosphorus cycle that would be more independent of foreign countries.