Attn
The Minister of Public Housing,
Spatial Planning and the Environment
PO Box 30945
2500 GX The Hague, The Netherlands

TCB S35(2007) The Hague, 17 July 2007

Subject: Advice on phosphate saturation in agricultural soils

Dear Madam Minister

In your letter dated 10 May 2007[1] (Appendix 1) you request advice from the Soil Protection Technical Committee [*Technische commissie bodembescherming -TCB*] with respect to the approach to phosphate saturation in Dutch agricultural soil. You make this request also on behalf of the ministries of Agriculture, Nature and Food Quality (LNV) and Transport, Public Works and Water Management (V&W).

The TCB has prepared this advice in consultation with a working group consisting of experts. The list of members of the working group is included in Appendix 2. Due to the short time available for drafting this advice, no separate report of the working group has been created. Instead, a substantiation of and background to this advice are included in Appendix 3.

INTRODUCTION

The TCB considers sustainable use of the soil to be a precondition for agricultural production. In addition, TCB considers the farmer to be the most important manager of the rural area. The phosphate saturation of agricultural soils is the result of years of supplying more phosphate to the soil than is removed with the harvested crop. Phosphate saturation increases the risk of phosphate leaching from the soil to the top groundwater layer and to the surface water. This contributes to the eutrophication of the surface water. High phosphate levels in agricultural soils can also have a negative influence on (agricultural) biodiversity. When agricultural land is taken out of production for nature development, phosphate saturation of the soil complicates the realisation of specific nature goals.

The total amount of phosphate supplied via animal manure and artificial fertiliser to the land is considerably greater than the total amount of phosphate removed via the harvested crop. The

---

[1] Reference BWL/2007017496

supply of phosphate is higher than agriculturally necessary. This is called the 'phosphate surplus'. This phosphate surplus is created because large amounts of phosphate are being imported via concentrates (and by-products) for the (supplementary) feeding of pigs, poultry and cows. By introducing the phosphate application standards in accordance with the principle of balanced fertilisation, the phosphate surplus in the Netherlands will grow, unless manure production and the use of phosphate in artificial fertiliser reduce considerably. In this context, the TCB argues for an effective set of policy measures to reduce the phosphate load in the Dutch soil, within the framework of a healthy agricultural commercial operation. The TCB is of the opinion that phosphate saturated land can only successfully be tackled if the manure surplus is driven back at the same time.

IN ANSWER TO YOUR QUESTIONS

Tailor the phosphate application standards to the phosphate status of the soil

You ask which possibilities the TCB envisages to tailor the phosphate application standards to the phosphate status of the soil. The TCB envisages the possibility of using differentiated phosphate application standards to contribute to driving back phosphate saturation in agricultural soils. The TCB recommends the use of the principles on which the current phosphate fertilisation recommendations are based as the basis for differentiated phosphate application standards.

The current fertiliser recommendations are among other things tuned to the availability of phosphate in the soil and to the phosphate need and uptake of the crop. The application of these recommendations can make a major contribution to the sustainable management of agricultural land and a reduction in the load in surface water. However, on many parcels of land more phosphate is supplied via animal manure and fertiliser than is necessary according to the fertiliser recommendations, in particular because animal manure currently has a negative price (the receiver of animal manure receives money). Therefore, differentiation will only be effective if sufficient stimuli are created to ensure that the fertiliser recommendations are actually adhered to.

The TCB proposes a functional classification in three parts on the basis of the availability of phosphate for agricultural production:

Low

In a situation where the phosphate status of the soil [2] is low for agriculture, it is reasonable to supply more phosphate to the soil than the amount that is removed when harvesting the crop. For crop production, the phosphate status of the soil will improve. This is in line with the current fertiliser recommendations and is also possible in the current legislation concerning manure;

Sufficient

In a situation where the phosphate status of the soil is sufficient for agriculture, the fertiliser recommendations based on balanced fertilisation are adhered to;

---

[2] As an indication, a Pw value or PAL (Phosphates Acetate Lactate) value of less than 20-30.

High

In situations where the phosphate status of the soil is more than sufficient or high for agriculture[3], phosphate fertilisation can be less than the uptake by the crop or can even be dispensed with completely. This is also in line with the current fertiliser recommendations. If more phosphate is extracted from the soil than is removed via harvesting the crop, the phosphate buffer in the soil will reduce and the probability of phosphate leaching to groundwater and surface water becomes less. Lowering the phosphate buffer in the soil has no consequences for agricultural productivity if the level of phosphate in the soil is high. Recent field studies have shown this empirically.

Differentiated phosphate application standards in accordance with the proposal above form a self-correcting system. Parcels of land in the category 'high' will gradually return to the category 'sufficient' for which balanced fertilisation applies. Parcels of land where in time the use of balanced fertilisation reduces the phosphate status of the cultivated soil as phosphate leaches out and/or is irreversibly bound in the soil, are eligible for additional phosphate supply as soon as the phosphate status becomes 'rather low' or 'low'.

Based on current insight, for almost every crop differentiated phosphate application standards do not lead to a reduction in the organic matter content in agricultural soil, with a possible exception being the cultivation of bulbs in '*geest*' soil (sandy soil between the dunes and polders) and the cultivation of trees.

Differentiation based on the basic principles of the fertiliser recommendations requires to be worked out in more detail and requires choices to be made for the practical implementation. In Appendix 3, TCB gives a number of suggestions for this further detailing. The scientific knowledge with respect to measuring the phosphate status of the soil is developing rapidly. The TCB recommends that this development be stimulated and to investigate how improvements in the measuring method can be implemented in the course of time in the fertiliser recommendations and in the phosphate application standards. When implementing the differentiated phosphate application standards, it is of great importance that they be supported by the agricultural sector, as ensuring that the proposed system is adhered to will not be easy.

If the differentiated phosphate application standards are introduced in 2015 in accordance with the proposal described above, in total 80 to 120 million kilograms less phosphate can be deposited on land than was the case in 2002, causing the manure surplus to increase. This underlines the importance of simultaneous action towards phosphate saturated soils and the manure surplus.

Only a limited number of countries in the European Union have formulated a targeted phosphate policy. Ireland has implemented legislation that is completely grafted onto the fertiliser recommendations, taking into account both the phosphate uptake by the crop and the phosphate status of the soil. In Flanders, rules have been formulated in the *Mestdecreet* [manure decree] for the use of phosphate fertilisers, with specific attention being given to phosphate deficient and phosphate saturated soil. In the other EU countries with a targeted phosphate policy, no account is taken of the phosphate status of the soil.

---

[3] As an indication, a Pw value or PAL value higher than 40-60, dependent on crop group, soil type and analysis method.

Phosphate saturation of the soil in relationship to phosphate load in surface water

You ask how the severity of the problem of phosphate saturated soil is related to the actual leaching of phosphate to the surface water. Phosphate saturated soils form a relevant source of phosphate load in the groundwater and surface water. The concentration of phosphate that leaches from the groundwater to the surface water, on a national scale is higher than the current 'operational standards' for phosphate (phosphorus) in surface water of the European Water Framework Directive (WFD). Realising the objectives of the European Water Framework Directive requires a reduction in the supply of phosphate from agricultural lands to the surface water. The WFD standards for surface water are still under development. The ambition for the 'ecological status' of the surface water will in the end determine the task of the agricultural sector.

The relationship between the degree of phosphate saturation of the soil and the phosphate concentration in surface water is complex. A multitude of factors determines the final transport of phosphate from the soil to the surface water. This results in major local and regional differences. The method currently being developed to characterise soils from phosphate leaking soil takes into account the phosphate status and the hydrological situation including the connectivity of the parcel of land to the surface water.

In drained land a clear relationship is found between the degree of phosphate saturation of the soil and the phosphate concentration in the drained water. A relationship between phosphate saturation of agricultural land and the phosphate load in the surface water is often not found in measurement programmes. Normally these measurement programmes have not been designed to detect these relationships and probably not all of factors that have an influence are taken into account in the analysis. The severity of the problem, however, must not just be derived from the measurements of the current leaching of phosphate. The current scientific knowledge of and insight into the relevant soil processes related to the binding and transport of phosphate in the soil give sufficient reason to take measures focussed on the source.

Effectiveness of phosphate extraction

Finally you ask under which circumstances phosphate extraction from phosphate saturated and phosphate leaking soil is an effective method of remediating phosphate saturated soils or combating phosphate leaking. Phosphate extraction is 'the removal of phosphate from the soil by harvesting and removing a crop, with (practically) no phosphate fertilisation'. The TCB mainly considers phosphate extraction to be an effective method of reducing a high phosphate status and a high phosphate concentration in the soil solution in cultivated soil.

There is a strong non-linear relationship between the phosphate buffer in the soil and the phosphate concentration in the soil solution. This means that for a relatively large reduction in the phosphate concentration in solution, the phosphate buffer hardly reduces. Nevertheless, the risk of leaching reduces markedly. Both model calculations and experimental measurements show that in 5 to 10 years both the phosphate status and the phosphate concentration in the cultivated soil can be strongly reduced. As a result, the risk of phosphate leaching into the groundwater and the surface water (phosphate leaking) will be strongly reduced locally. Within several years, this can lead to a noticeable improvement in the water quality of nearby surface water. Phosphate extraction becomes even more effective if it is combined with supplementary measures such as dredging ditches, installing helofyte filters, and the implementation of other water management measures. When the phosphate saturation front has permeated deeper into the soil than the crop roots, phosphate extraction is less effective in combating the phosphate load in the surface water.

In the short term, phosphate extraction has only a limited influence on the reduction of the total buffer of phosphate in the soil; the amount of phosphate to be removed via phosphate extraction is relatively low when compared to the total amount of phosphate, up to 10,000 kg phosphate per hectare in the top 50 cm, that has accumulated in the topsoil of agricultural land. Furthermore, phosphate extraction becomes less effective in the course of time. For nature development on former agricultural lands, it will take several tens to hundreds of years to remediate the total amount of phosphate in the soil through phosphate extraction. Therefore developing a natural environment, which requires a very low phosphate status of the soil, will require a lot of perseverance. For this reason, for nature development, the choice is often made to excavate the nutrient rich top layer of the soil. The disadvantage of this is that it is expensive and that the seeds present in the soil are also removed.

The application of the differentiated phosphate application standards as proposed by the TCB will also lead to removal of phosphate from phosphate saturated soil. On approximately 30 percent of the total agricultural acreage, crops can grow without supplementary phosphate fertilisation and without any loss of yield. The (agricultural) biodiversity can increase, when, due to a reduction in or no fertilisation, the amount of nitrogen in the soil also reduces. Plant species such as dandelion and cuckoo flower will appear in the grassland, which attracts insects and with it (farmland) birds.

RECOMMENDATIONS

Develop differentiated phosphate application standards based on the basic principles of the current fertiliser recommendations for phosphate.

Employ three classifications: for a low phosphate status in which more phosphate can be applied than is allowed according to balanced fertilisation; for a satisfactory phosphate status in which fertilisation can occur in accordance with balanced fertilisation (the supply of phosphate via fertilisation is equal to that removed with the harvested crop); and for a high phosphate status in which no phosphate is supplied with the result that the phosphate status of the soil will reduce. If required, specific crops can be exempted.

Work out this form of differentiated phosphate application standard in more detail. When doing so, pay attention to the practical feasibility and encourage and obtain the support of farmers. Remove the possible fear of a loss of yield by creating demonstration fields.

Develop a policy to drive back the 'manure surplus'. Eliminate the financial benefit that ensures that more phosphate is used via animal manure than is prescribed by the application standards (animal manure as a 'fourth crop'). Use the results from research and provide information to companies to limit the use of artificial phosphate fertiliser, and consider a ban on using artificial phosphate fertiliser on land that has a sufficient or high phosphate status. Arrange that there is less phosphate in animal food, and create more alternatives for processing manure. If the effect of this proves to be insufficient, it may become necessary to reduce the total number of livestock.

Take into account recent scientific developments related to measuring and interpreting the phosphate status of the soil. Develop and implement a strategy to measure the quality of surface water in which the influence of various sources of eutrophication can be distinguished. Using this data, the correct source- and effect-targeted measures can be identified.

At the same time, in addition to the system of differentiated phosphate application standards as described in this document, put into effect effect-targeted measures, such as dredging, in order to reduce the phosphate load in the surface water as quickly as possible.

Consider phosphate application standards as part of a total package of measures to combat the eutrophication of the surface water, and if required, tailor these standards to the local situation in relation to the objectives set out in the Water Framework Directive.

Yours faithfully,
the chairman of the
Soil Protection Technical Committee,

Ir. L.E. Stolker-Nanninga

Appendices:
1. The request for advice
2. Members of the temporary TCB working group on phosphate saturated soils
3. Substantiation of the advice on phosphate saturation in agricultural soils

APPENDIX 1. THE REQUEST FOR ADVICE

APPENDIX 2. MEMBERS OF THE TEMPORARY TCB WORKING GROUP ON PHOSPHATE SATURATED SOILS

Prof.dr.ir. O. Oenema, Alterra, Wageningen, chairman, also a member of TCB;

Prof.dr. J.G.M. Roelofs, Radboud University Nijmegen, also a member of TCB;

Prof.dr.ir. G. Hofman, University of Gent, Belgium;

Pro.dr.f W.H. van Riemsdijk, Wageningen University;

Ir. O.F. Schoumans, Alterra, Wageningen;

Dr.ir. H. van de Weerd, RIZA, Lelystad;

Ir. J. Verloop, Plant Research International, Wageningen;

Dr A.J.P. Smolders, Radboud University Nijmegen;

Ir. L.J.M. Boumans, RIVM, Bilthoven.

TCB-Secretaries: Drs. J. Tuinstra and Dr A.E. Boekhold

APPENDIX 3.

SUBSTANTIATION OF THE ADVICE ON PHOSPHATE SATURATION IN AGRICULTURAL SOILS

DEFINITION OF THE PROBLEM

Phosphate saturated soils in the Netherlands

It is estimated that 50-60 percent of the acreage of agricultural land in the Netherlands is saturated with phosphate (Figure 1; Schoumans, 2004). The more they are saturated, the more these soils contain considerably more phosphate than is required for agriculture. Dependent on the hydrological situation and the location of the parcel of land in relationship to the location of the surface water, these soils contribute to the phosphate load in the groundwater and surface water, and can be considered to be phosphate leaking soils (Schoumans *et al*., in preparation). It is therefore desirable to drive back the phosphate load in the soil.

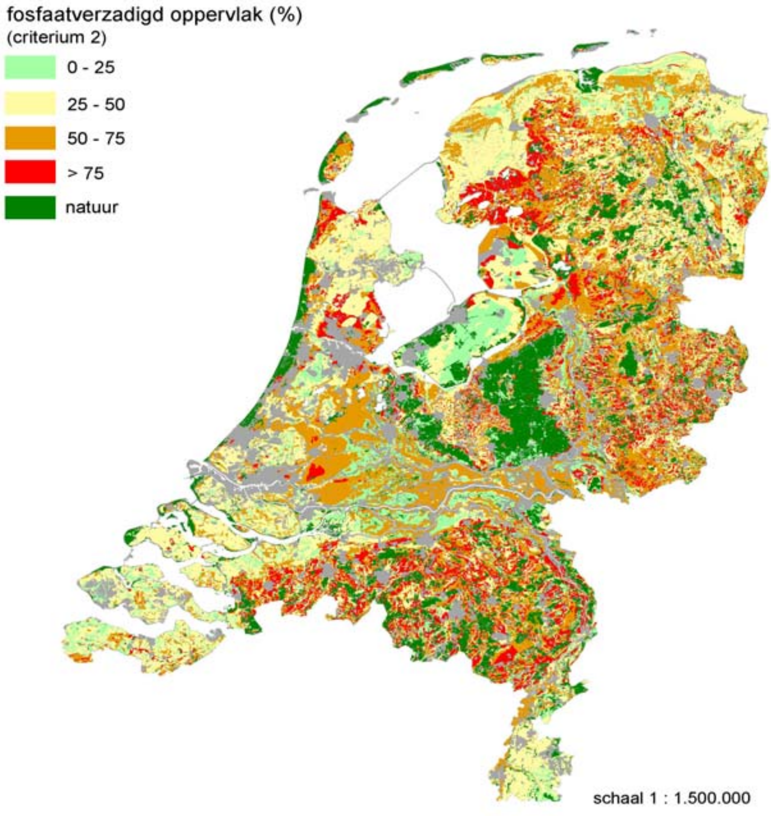

Figure 1. Phosphate saturated soils in the Netherlands as measured in the period 1992-1998. For agricultural land, four classes have been distinguished that take into account a criterion for the degree of phosphate saturation for specific types of soil, referred to as Criterion 2. Source: Schoumans, 2004.

The figure above is based on measurements in the period 1992-1998. Urgent areas are in particular the agricultural lands in the valleys of riverlets and other low-lying agricultural land in sandy areas in the south and east of the Netherlands. This is due to the unfavourable combination of a concentration of intensive livestock industry and soils sensitive to leaching. In recent years, the prevailing manure policy made it possible to supply more phosphate via animal manure and fertiliser than was removed via the crop (phosphate surplus). A recent inventory shows that the phosphate surpluses in the agricultural sector have, it is true, dropped from on average 40-60 kg P_2O_5 per hectare per year (in the mid nineties) to an average of 20-40 kg P_2O_5 per hectare in 2005[4] (Van der Ham *et al.*, in preparation), however, this is still a surplus. Based on this, in the past decade, an additional several hundreds of kg of P_2O_5 per hectare have accumulated in the agricultural soils. As a result, the situation as shown in Figure 1 has actually deteriorated, resulting in a further increase in the area of agricultural land that is phosphate saturated in recent years. As a result, the phosphate concentration in the upper groundwater will also in the course of time be higher than the situation mapped out for the period 1992-1998 (Schoumans, 2004).

From the perspective of the efficient use of the limited worldwide stocks of easily extracted raw phosphate, the phosphate saturation of agricultural soils is in itself an unsustainable situation. In about 100 years, the stock of easily extracted raw phosphate will have been depleted, and the costs for extracting raw phosphate will increase (Laegreid *et al.*, 1999). Poor countries, where the soil is naturally phosphate deficient, will, if phosphate fertiliser becomes more expensive, have ever more problems producing sufficient food.

Phosphate concentration in the soil solution and the amount of phosphate

Phosphate (P_2O_5) is strongly bound in the soil, which means that the amount of phosphate in the soil solution is relatively small. In the solid phase, a distinction can be made between a fraction of easily exchangeable phosphate (reversibly bound phosphate) and a fraction of difficult to exchange phosphate (irreversibly bound phosphate). The distribution in the soil solution and both solid phases depends on the environmental conditions (in particular the pH), the composition of the soil (in particular the aluminium and ferrous compounds and the organic matter content) and the total phosphate concentration in the soil.

Plant roots take up phosphate from the soil solution, resulting in a reduced concentration. The amount of phosphate in the soil solution is in case of uptake supplemented by the exchangeable fraction in the soil, in other words: the soil operates as a buffer. The amount of phosphate adsorbed in the solid phase of the soil will then reduce somewhat.

The relationship between the amount of phosphate bound to the solid phase in the soil and the amount of phosphate in the soil solution is shown in an adsorption or desorption isotherm. The general shape of this isotherm for phosphate in the soil is shown in Figure 2. The relationship is not directly proportional. If a large proportion of the phosphate sorption capacity has been used, the phosphate concentration in the soil solution increases more than proportionally, and with it the risk of phosphate leaching to the subsoil, the groundwater and the surface water. The relationship depends on the soil composition and the environmental conditions. This figure shows the results of a pot experiment in which the plant uptake ensured that the phosphate content in the soil reduced (phosphate extraction). In this pot experiment, which relates to the top 10 centimetres of the cultivated soil, the reduction in

---

[4] The variation is determined by the various regions and sectors.

the total amount of phosphate in the soil progresses considerably faster than expected in field situations.

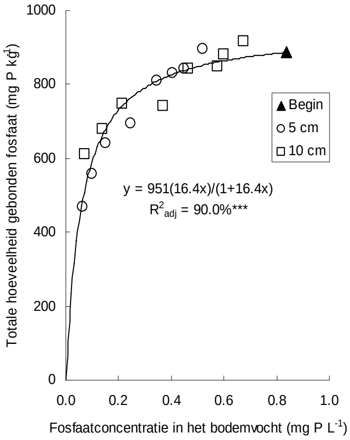

Fig 2. The relationship between the phosphate concentration in the soil solution (x-axis) and the total amount of bound phosphate (y-axis) at depths of 5 and 10 centimetres, based on a 30-day pot experiment. The circles and squares show the experimental results, the line reflects the theory. Source: Koopmans, 2004.

Phosphate status

The normally used agricultural term to indicate the amount of phosphate in the soil that is available to the crop is the phosphate status. In the current fertiliser recommendations for this phosphate status the term Pw value (expressed in mg phosphate per litre of soil) and/or the PAL value (expressed in mg phosphate per 100 g of soil) is used. The Pw value gives the amount of phosphate that occurs in the soil solution plus a proportion of the amount of easily exchangeable phosphate. In addition, the PAL value includes a proportion of the difficult to exchange phosphate. A Pw value of 20-25 corresponds to a directly available amount of phosphate of 40-50 kg phosphate per ha and a Pw value of 40-45 corresponds to 80-90 kg phosphate per hectare, dependent on the crop.

A proper determination of the phosphate status actually requires at least two measurements, as the phosphate status is determined by the concentration in the soil solution as well as by the amount of phosphate bound to the soil. The current single-point measurements (Pw and PAL) are therefore a practical compromise. Investigations are being carried out into improving the measuring method.

Phosphate saturated soil and phosphate leaking soil

The total amount of phosphate that can be bound to the soil is called the phosphate-binding capacity (or phosphate-sorption capacity), which differs per soil type. The phosphate-binding capacity also depends on the concentration in the soil solution. For agricultural soils that are considered to be phosphate saturated, the phosphate binding capacity has been used to such an extent that the phosphate concentration in the soil solution has increased to a level at which there can be an increase in the phosphate load in the upper groundwater (at the level of the average highest groundwater level; concentrations higher than 0.10 mg ortho-P per litre or 0.15 mg total P per litre; see TCB, 1990).

Dependent on the degree of phosphate saturation of the soil and the hydrological circumstances, this can result in actual phosphate leaching to the surface water. These are referred to as phosphate leaking soils (Schoumans *et al.*, in preparation).

Phosphate and ecology

The European Water Framework Directive (WFD) places requirements on the quality of the surface water in the member states. For 'natural' waters, the objective is to achieve a good ecological condition. With respect to phosphate, for the Dutch situation preliminary water-type-specific operational standards have been drawn up, which for natural waters vary between 0.03 and 0.14

mg P per litre. If these levels are exceeded, eutrophication of the surface water has occurred, which can lead to an up to 80 percent reduction in potential biodiversity. The final standards for non-natural waters must still be specified.

On the national scale, the median total P concentration in regional surface water has halved, from approximately 0.4 mg/L in 1985 to approximately 0.2 mg/L in 2002 (MNP, 2005), but this is still above the highest operational standards. The future WFD standards for surface water will possibly allow higher contents locally (differentiation in standards), but a general liberalisation of the phosphate standards is not expected**.** This means that considerable efforts are required to reduce the phosphate load in the surface water sufficiently.

A surplus of phosphate in the soil of (former) agricultural land intended for nature development can lead to less biodiversity than desired, which complicates the development of nature on such land. However, in general, the effect of nitrogen fertilisation is greater than the effect of phosphate fertilisation (see box).

Phosphate and biodiversity

Species-rich vegetation, such as low nutrient biodiverse grassland (for instance bluegrass land that nature policy values highly) can only develop on P-limited soils (Wassen *et al*., 2005; Smolders *et al*., 2006). When the P-status is higher, herb-rich grasslands can develop, with species such as cuckoo flower, dandelion and buttercup (Korevaar *et al*., 2006). In situations in which this desired species diversity was hard to achieve, there was normally a high supply of nitrogen (from buffers in the soil) or the required seeds were not present in the soil.

When changing land use from agriculture to nature, a high level of phosphate in the soil forms an impediment to the development of very biodiverse vegetation. The desired natural environment can only be realised after, for instance, excavating the nutrient-rich top layer. However, this is not always a solution, as high levels of phosphate can also be present at greater depths. Where limited areas are concerned, excavating to a depth of up to 40 centimetres is still practically feasible, but it is expensive and the seeds that are present in the soil are also removed at the same time.

An excess of phosphate in the soil can lead to the ecological connecting zones being impenetrable for certain plants. These zones form connections between nature areas, along which organisms can migrate from the one area to the other. Many plants that nature policy values highly do not survive these high levels of phosphate. As a result, the zones loose their connecting function for these plants.

Another problem that can arise when changing the function of land from agriculture to nature is an increase in phosphate that leaks into the groundwater. This for instance occurs when the watertable is raised in grasslands. Large amounts of phosphate are released in the anaerobe environment that is created. This can be seen in the vegetation in the increase of undesired soft rush vegetation.

DIFFERENTIATING PHOSPHATE APPLICATION STANDARDS

Phosphate application standards can be differentiated for agricultural and environmental motives. Agricultural motives are the differences in phosphate needed by different crops, and differences in the phosphate supply that is required to keep the phosphate availability in the various soil types at the desired level. The agricultural position takes into account the fact that land that has a low phosphate status must be compensated with an additional supply of phosphate. Environmental motives for differentiation are the differences in the sensitivity to leaching phosphate to the groundwater and surface water and the nature value of the agricultural landscape. The TCB assumes an approach that combines the agricultural and the environmental motives (see the answer to question 1).

In line with the agreements made with the EU, the Netherlands is working towards balanced fertilisation in 2015. This means that the supply of phosphate to the soil will then correspond to the removal of phosphate via the harvested crop. According to this interpretation of balanced fertilisation, no account is taken of the phosphate that is already present in the soil.

Balanced fertilisation

In this advice, balanced fertilisation is understood to mean that the supply of phosphate via animal manure and fertiliser is equal to the phosphate removed via the crop. This does not include the 'unavoidable agricultural and environmental losses'. The term balanced fertilisation is not defined unambiguously. In practice, various interpretations are being used. For instance, sources of supply are not clearly delineated and 'unavoidable losses' can be part of the definition.

Fertiliser

In the Dutch Fertilisers Act the term 'fertiliser' has a wide definition. In addition to animal manure and artificial fertiliser, other organic and inorganic fertilisers are identified. This latter category also includes the return flows from the agricultural processing industry, provided that they are designated as such by the Minister of LNV (Ministry of Agriculture, Nature and Food Quality) via the Positive List. The phosphate in all fertilisers counts when determining the total phosphate supply; for compost, only a proportion of the phosphate present is included. The proportion of return flows in the total use of fertiliser is limited, but can have local importance.

The Dutch government is currently investigating the options of tailoring the phosphate application standards to the phosphate status of the soil. The generically formulated phosphate application standards in the third Netherlands Action Programme within the framework of the European nitrate directive of 60 kg P_2O_5 per hectare per year for farmland and 90 kg P_2O_5 per hectare per year for grassland are indicative values at the level of balanced fertilisation. As this level is too low for phosphate-deficient soil, the current fertilisation policy offers the opportunity to supply additional phosphate to phosphate-deficient soil (for four consecutive years a maximum of 160 kg P_2O_5 per ha). The acreage of phosphate-deficient land in the Netherlands is small (approximately 2-7 percent, Schoumans *et al*., 2004a). The reason that the Netherlands still has agricultural land with a low phosphate status is mainly caused by deep ploughing, the levelling of land, liming and drainage. These actions raise soil with a low phosphate status up from the subsoil to the surface, or the available phosphate is irreversibly bound in the soil. Currently no limitations apply to phosphate-rich land with respect to the phosphate supply; generic phosphate application standards are currently higher than required for optimum crop production.

Agricultural land with a high phosphate status in the cultivated soil can in general manage without phosphate fertilisation, without this having any consequences for production or the quality of the crop. Recent field studies have demonstrated this empirically (Neeteson *et al*., 2006). Even without further phosphate fertilisation, these soils can already show phosphate saturation or phosphate leaking (Schoumans *et al*., in preparation).

In Flanders there is currently a ban on the use of artificial phosphate fertilisers for certain crops if the phosphate status of the soil is high. There are a number of precisely described exceptions to this ban. For the cultivation of certain fast-growing leaf vegetables and vegetable crops with a shallow and poorly developed root system in the open ground (for instance spinach, lettuce, leek), phosphate fertiliser is important for a high quality yield. However, the acreage of these crops in the Netherlands is very limited (less than 1 percent). For this reason, these crops can be exempted on a national scale from any limitations in the use of artificial phosphate fertilisers on phosphate-rich soil without any environmental consequences.

Assuming approximately 2 million hectares of agricultural land, 1 million hectares of which is farmland and land used to grow maize, and the proposed generic phosphate application standards of 60 kg phosphate per hectare per year for farmland and 90 kg phosphate per hectare per year for grassland, a maximum of 150 million kg of phosphate can be supplied annually. The supply of phosphate by means of artificial fertiliser in the period 1998-2002 varied between 50 and 70 million kg per year, and that of animal manure varied between 160 and 200 million kg per year. In 2006, the total amount of phosphate in animal manure was approximately 160 million kg (Luesink, in preparation). This implies that when introducing generic phosphate application standards between 2002 and 2015, the total agricultural phosphate supply must reduce by 50 to 80 million kg annually. In recent years, 10 to 20 million kg of phosphate was exported annually.

With the differentiation of the phosphate application standards in accordance with the answer to question 1, account is taken of the phosphate status of the soil. According to Schoumans (2007a), in the period 1998-2003 on average 23 percent of the soil samples from grassland analysed by the *Bedrijfslaboratorium voor Gewas- en Grondonderzoek* [a laboratory specialised in crop and soil research] (BLGG) had a high phosphate status. For soil samples from land used to grow maize and farmland this percentage was 43 and 31 percent respectively. Assuming that the soil samples taken give a representative picture of the entire agricultural acreage, approximately 28 percent of the agricultural acreage has a high phosphate status, and therefore according to the fertiliser recommendations does not need any additional phosphate. In total, 2-7 percent of the agricultural acreage had a low to rather low phosphate status, for which an additional phosphate supply is desirable (Schoumans *et al*., 2004a). As there is more phosphate-rich than phosphate-deficient agricultural land, the use of differentiated phosphate application standards would result in a total reduction in phosphate application of between 30 to 40 million kg annually when compared to the amount applied if generic phosphate application standards were used. This means that the implementation of differentiated phosphate application standards in 2015 would result in a total reduction in phosphate application of up to 80 to 120 million kg when compared to 2002, which means a substantial increase in the manure surplus. In addition to stringent limitations on the use of artificial phosphate fertiliser, a limitation in the supply of phosphate via animal manure is required (less phosphorous in the food, manure processing, manure export, etc.).

RELATIONSHIP WITH THE MANURE SURPLUS IN THE NETHERLANDS

Differentiating the phosphate application standards with respect to the phosphate status of the soil will only be effective if at the same time action is taken to reduce the supply of animal fertilisers. Without driving back the supply of phosphate in animal manure, differentiation will result in ever increasing pressure on the manure market. Without a reduction in the not-to-be-spread-on-land and the non-processable 'manure surplus', differentiation will promote fraud with respect to the fertiliser legislation. Measures are being argued for that would make recovering phosphate from a wide variety of agricultural flows (manure, agro industry) competitive with respect to the unprocessed spread over land.

Since the beginning of the nineteen sixties, the large amount of animal manure on the fertiliser market in the Netherlands has been caused in the main by intensive agriculture, and then in particular pig and poultry farming. This sector imports (raw materials for) feed on a large scale (including soya). The meat produced is mainly exported, (semi-liquid) manure remains as a by-product. The amounts of this manure exceed the need for fertiliser for the soil in the Netherlands, in spite of the relatively high fertiliser requirement in the highly productive Dutch agriculture. Locally, the phosphate surpluses at the company level are enormous, in particular in the provinces of North Brabant and Gelderland, and large quantities must be transported to other areas (MNP, 2004).

The problem has been known for many years (Henkens, 1969; De la Lande Cremer, 1970; Breeuwsma and Schoumans, 1986)**.** Solutions are possible, but only if drastic measures are taken, such as a ban on the use of artificial phosphate fertiliser, the far-reaching intensification of manure processing, including manure sorting and export, which would lead to a substantial increase in the processing costs, or, if it comes to the worst, a reduction in the total number of livestock. A reduction in the amount of phosphate in animal food could also contribute to driving back the phosphate load in the soil in the Netherlands. The TCB considers the sustainable use of the soil to be a binding precondition for agricultural production, and therefore argues for a more effective set of policy measures to reduce the impact of phosphates on the Dutch soil. The large amount of phosphate supplied via animal manure has been standing in the way of solving the phosphate problem in the Netherlands for many years.

RELATIONSHIP WITH THE PHOSPHATE LOAD IN THE SURFACE WATER

Due to the nutrient load, the majority of Dutch surface water is subject to eutrophication. In more than half of the measurement locations in surface water, the phosphate concentrations are above the Maximum Allowable Risk (MTR) level (Bakker and Plette, 2007). The impact of phosphate from agricultural land plays an important role here (Table 1; MNP, 2005).

Table 1 Load in Dutch surface water of phosphorus due to emissions, leaching and runoff and rivers that cross the borders. Load in million kg/year. Source: MNP, 2005.

Source	1985	1995	2002
Industry	13.4	3.5	0.6
Effluent from RWZIs[1]	10.8	3.5	3.0
Other communal sources[2]	2.6	0.4	0.2
Leaching /runoff[3]	4.8	5.0	5.9
from agricultural land	4.4	4.6	5.5
Agriculture direct	0.8	0.4	0.4
Total of national sources	32.4	12.8	10.1
Rhine, Meuse and Schelde rivers	43.4	23.3	26.8

[1] Sewage treatment plants.

[2] Built-on surfaces without drainage, runoff from paved surfaces, sewer overflows.

[3] Contribution from agricultural land on average 92 percent, the other 8 percent comes from nature areas.

The most important sources of phosphate in surface water are the sewage treatment plants, industry and diffuse load from the rural areas. The amount of phosphate carried by the rivers is relatively high, but due to the high water flow, with respect to concentrations low. The ecological quality of the surface water that is fed by the Rhine has improved enormously in recent years. However, this improvement cannot yet be seen in water systems that are influenced by agriculture. The load from rural areas is in the main caused by the runoff and leaching out of fertiliser from parcels of land being used for agriculture. Regionally, phosphate-rich seepage (for instance in areas with marine deposits in the subsoil, such as in sea clay areas and peat areas), can lead to an increased phosphate load (Van Beek, 2007). The load from sewage treatment plants and industry reduced significantly in the period from 1985 to 2005 (reduction of 82 percent to 2002, see Table 1). The contribution from rural areas has remained more or less the same from 1985. The consequence is that the phosphate load in the surface water from rural areas is currently the largest source of phosphate. Contrary to the other sources, the contribution from rural areas shows major variations in both time and location; leaching mainly occurs in winter and is higher in wet years than in dry ones (Van de Weerd and Torenbeek, 2007; Schoumans and Kruijne, 1995b; Schoumans et al, 2002; MNP, 2005).

The relationship between phosphate status and the degree of phosphate saturation of the soil and phosphate load in the surface water is complex and is locally determined by soil type and hydrological circumstances, including the connectivity of the parcel of land to the surface water (Haygarth and Jarvis, 2002; Dawson and Johnston, 2006; Schoumans *et al*., in preparation). The concentration of phosphate in the surface water can only be predicted from the concentration of phosphate in the soil if the local system characteristics (soil structure, sources, soil processes, hydrology and position) are known and can be quantified.

It must be emphasised that even with a good understanding of the system there will still be uncertainties in quantifying the local relationship between the phosphate levels in the soil and the concentrations of phosphate in the surface water. This is the result of the intrinsic heterogeneity of the soil and the fact that various processes occur in the surface water. Calculation models that describe this behaviour of substances in the soil and groundwater can, via stochastic modelling, discount this. The uncertainty in the prediction of the behaviour of substances in the soil and the groundwater is general and fundamental. The uncertainty certainly applies with respect to predictions concerning the local quality of the surface water. However, this does not alter the fact that at the macro level, agriculture now makes the largest contribution to the phosphate load in surface water.

Source measures, targeted at reducing the supply of phosphate to the soil are therefore important in order to structurally drive back phosphate emissions to the surface water. However, if only source measures are employed, it can take several decades before any effect on the quality of the surface water is noticeable. Effect-targeted measures at the parcel of land level, such as extraction and measures that limit removal via runoff can locally relatively quickly lead to a reduction in the phosphate load in surface waters. It is unclear to which degree a reduction in accordance with the WFD objectives can be achieved on a national scale using effect-targeted measures.

The ambition for the ecological condition of the surface water and the resulting criteria for the quality of the surface water will finally determine the time in which phosphate saturated and phosphate leaking soils will continue to pose a problem. This ambition will also determine the size of the task for the agricultural sector.

MORE SUSTAINABLE SOIL USE IN AGRICULTURE

In 2005, on the request of the Minister of Agriculture and also on behalf of the secretary of state of Transport, Spatial Planning and the Environment, the TCB issued advice with respect to sustainable soil use in agriculture[5]. In this advice, the TCB formulated basic principles for more sustainable soil use. Sustainable soil use takes as its basis the services provided by the soil. These services must be maintained in such a way that the restorative capacity of the soil remains intact. The depletion or destruction of these services must be prevented. The use of the soil ecosystem should not place a load on the environment, such as the groundwater and adjacent ecosystems. The TCB applied these general principles when answering the questions asked.

ANSWERS TO THE QUESTIONS POSED

Question 1

Which possibilities do you see to tailor the phosphate application standards to the phosphate status of the soil? Here I ask you to take into account:

- the degree to which the phosphate in the soil is available to the crop;
- possible side effects as a result of a change in the organic substances in the soil in the long term;
- the manner in which other member states deal with this matter (e.g. Morgan's index in Ireland) and the applicability of these insights in the Netherlands.

---

[5] Advies Duurzamer bodemgebruik in de landbouw, TCB A36(2005) [Advice on more sustainable agricultural soil use]

The current fertiliser recommendations (e.g. Commissie Bemesting Grasland en Voedergewassen 2007; Van Dijk *et al.*, 2003; Van Dam *et al.*, 2004) are among other things tailored to the availability of phosphate in the soil in relationship to the phosphate need and the phosphate uptake of the crop. Although these recommendations are more inspired by agricultural than by environmental issues, their application will make a major contribution to sustainable soil management and a reduction in the phosphate load in surface waters. The fertiliser recommendations lead to a phosphate surplus in the soil when growing certain crops, but this only occurs to a limited degree. Therefore, the TCB recommends using the principles of these fertiliser recommendations as the basis for differentiated phosphate application standards. The current fertiliser recommendations are well founded, are in line with the practical situation, but take the quality of surface water into account insufficiently (Schoumans *et al.*, 1991; Schoumans and Groenendijk, 2000; Schoumans and Lepelaar, 1995; Neeteson *et al.*, 2006). In addition, improvements can be made to the measuring methods and their interpretation.

A lower phosphate status of the soil is also necessary to arrive at more sustainable agriculture. The current bacteria-dominated ecosystems in soils that are intensively used for agriculture can, in the event of lower nutrient levels, return to systems with a higher fungal/ bacterial ratio (Van der Wal *et al.*, 2006; De Vries *et al.*, 2006). Soils that have a higher fungal/bacterial ratio are more capable of supplying ecosystem services, such as natural soil fertility, good soil structure and natural resistance to disease and infestation. Here not only fungi, but also other organisms play a role (Johansson *et al.*, 2004; Hamel, 2004; Esperschütz *et al.*, 2007). As a result, less external *inputs* (fertiliser, pesticides, herbicides) are necessary for the production of the crop and relatively less negative effects take place. In this type of more sustainable agriculture, the crop yield is normally somewhat less than in normal agriculture, but costs are also lower (Mäder *et al.*, 2002).

Giving recommendations does not necessarily mean that they are followed. For various considerations, farmers do not adhere to the fertiliser recommendations. An important agricultural consideration is the presumed risk of a possible loss of yield as a result of insufficient fertilisation. In addition, farmers receive an appreciable income from the payment they receive for the animal manure they accept (animal manure as the 'fourth crop'), which makes applying more fertiliser than the fertiliser recommendations suggest attractive. This is also shown in the results of mineral balances at company level, in accordance with the MINAS system (which has now been dispensed with) in relation to the average phosphate status of the soil (MNP, 2004). The introduction of stimuli is being argued for, which would lead to the differentiated phosphate application standards being adhered to. This requires an effective transfer of knowledge regarding soil research, fertilisation and crop yield to the practical situation. Measures are required to eliminate the benefit of the income received by accepting animal manure.

As the basis for the differentiation of the phosphate application standards, the principle that can be used is an agricultural-functional classification in three parts, based on both the phosphate status of the soil and the phosphate uptake by the (type) of crop:

Low
A situation with an agriculturally low phosphate status of the soil; then an additional supply of phosphate (above the supply coming from balanced fertilisation) is reasonable. This regulation is already possible within the current fertiliser legislation;

Sufficient
A situation with an agriculturally sufficient phosphate status of the soil. Phosphate application standards can be based on balanced fertilisation, meaning that the phosphate supply is equal to the phosphate removal via the harvested product (net phosphate uptake by the crop);

High
A situation with an agricultural high phosphate status of the soil; phosphate fertilisation can be dispensed with without any consequences for productivity. This leads to a reduction of the phosphate buffer in the soil.

Differentiation based on this classification must be worked out in more detail to arrive at usable phosphate application standards. This will require numerous practical choices and decisions to be made. For instance, to determine the category of the phosphate status of a soil, one needs to know the P status of the soil, therefore the soil must have been analysed. The scientific insight with respect to measuring the phosphate status of the soil is developing rapidly (Houba and Temminghof, 1999; Koopmans *et al.*, 2004; Van Rotterdam-Los (in preparation)). Within the framework of the phosphate application standards, the recommendation is to promote its further development and to test it in practice. However, differentiation can also be worked out using an approach based on an area or region, if a generic differentiation leads to too many shortcomings. In addition, phosphate fertilisation can be differentiated with respect to groups of crop that can be distinguished based on their phosphate uptake and phosphate demand.

Many farmers find it important to give an initial dose of phosphate at the start of the growing season, as this is supposed to promote the growth of the crop. However, this initial stronger growth does not always appear to be necessary (Neeteson *et al.*, 2006; Van Noordwijk *et al*., 1990). Apparently, a crop that does not get an initial dose redresses any possible lack in growth later in the growing season. The water supply to the crop and the temperature of the soil influences the reaction of the crop to an initial dose. With a proper water supply and soil that is not too cold, the effect of an initial dose is limited. This implies that improving the water supply in the early spring can be more effective for the supply of phosphate to the crop than an initial dose.

Differentiated phosphate application standards in accordance with the TCB proposal is not expected to lead to negative consequences for the amount of organic matter in agricultural soils. A possible exception to this is bulb growing on '*geest*' soil (sandy soil between the dunes and polders), where organic matter degrades relatively rapidly (Ten Berge *et al.*, 2007). In tree cultivation as well, where removing the ball of earth around the roots during harvesting also removes the organic humus-rich top soil, attention is required for the development of organic matter. For these sectors, it is recommended to investigate the way in which the agricultural side effects can be avoided as far as possible, for instance by using low-phosphate organic fertiliser and compost.

If the phosphate content in animal feed is reduced, the supply of organic matter to the soil can increase within the current application standards for nitrogen and phosphate; after all, more animal manure can be spread over the land.

The supply of organic matter to Dutch agricultural land is relatively high. The situation is one of a relatively low rate of mineralisation (wet soils) and high agricultural production causing abundant root and leaf residues to remain on the land. The organic matter content in agricultural soils appears to be increasing rather than decreasing in the Netherlands (Reijneveld *et al*., (in *review*).

A recently made inventory of the legislation concerned with the use of phosphates in the various EU countries (Schoumans, 2007b) shows that only a limited number of countries has a targeted phosphate policy. Ireland has implemented legislation that is completely grafted onto the fertiliser recommendations, taking into account both the phosphate uptake by the crop and the phosphate status of the soil. In Flanders, rules have been formulated in the *Mestdecreet* [manure decree] for the use of phosphate fertilisers, with specific attention being given to phosphate deficient and phosphate saturated soil. In the other EU countries with a targeted phosphate policy, no account is taken of the phosphate status of the soil.

Question 2

How does the severity (in the qualitative sense) of the problem of phosphate saturated soils relate to the actual leaching of phosphate to the surface water? Here I want to ask you to include the current knowledge concerning the factors that contribute to the leaking of phosphate from phosphate saturated soils.

Studies that quantify the leaching and runoff of phosphate from agricultural soils to surface water based on measurements are scarce. Results are available from *case* studies at three diary farms on sand, clay and peat (Torenbeek, 2003, Van den Eertwegh and Van Beek, 2004, Van der Salm *et al*., 2006, Van de Weerd and Torenbeek, 2007). However, these were not phosphate saturated soils. The transport route of phosphate to the surface water is determined by the surface morphology and the ditches in the land, the dynamics in groundwater levels, precipitation distribution and intensity and the time and manner of fertilisation. Dependent on the fertilisation, the contribution from *runoff* on the parcels of land studied was relatively high, varying from 0 to 85 percent. The contribution of shallow leaching depends on the phosphate status of the upper layer of the soil.

The RIVM manages the '*Landelijk Meetnet effecten Mestbeleid*' [national network measuring the effects of the fertiliser policy] (LMM). According to this network, the measured concentrations of phosphate in the shallow groundwater are relatively low in relation to the phosphate concentrations that are measured in the surface water. RIVM's measuring network was originally designed to monitor the nitrate concentrations in agricultural water at agricultural companies. Phosphate is also being measured, but details regarding the phosphate saturation of the soil are not available from the LMM.

The actual load on the surface water can differ strongly, because for equal degrees of phosphate saturation but with differing groundwater levels, the emissions to the surface water will be different. Experimental measurements show that an increase in the degree of phosphate saturation in the soil is associated with an increase in the phosphate concentration in the drained water. This is illustrated by the measurement results in drained water, as presented in Table 2. The results show that in water drained from the parcels of land that have the highest degrees of phosphate saturation, the highest ortho-phosphate concentrations are also measured. It must be stated that the drain depths were not always equal. The highest value (2.47 mg/L ortho-phosphate) was measured in a shallow drain (40 cm depth) (Brookes *et al.*, 1997; VLM, 1997).

Table 2 Relationship between the percentage P saturation and the ortho-P-concentration in drained water. Source: VLM, 1997.

Plot	% phosphate saturation	mg o-P/L (average) in drained water
1	24	0.01
2	31	0.10
3	32	0.03
4	33	0.05
5	33	0.10
6	34	0.02
7	38	0.05
8	38	0.15
9	40	0.25
10	41	0.05
11	42	0.02
12	44	0.07
13	45	0.40
14	47	0.06
15	48	0.07
16	48	0.20
17	49	0.02
18	49	1.23
19	51	2.47
20	53	0.95
21	54	0.90
22	55	1.01
23	56	1.33
24	58	0.68
25	62	0.50

Field studies show that shallow leaching through the soil and runoff from ground level after fertilisation, followed by precipitation, can make an important contribution to the supply of the local phosphate load in the surface water (Schoumans and Kruijne, 1995a, Van de Weerd and Torenbeek, 2007). In the event of a more frequent occurrence of high precipitation levels, as is expected as a result of climate change, the local phosphate load in the surface water at ground level will possibly increase further in the future.

Via area studies, the importance of various sources can be determined on a regional scale. In the project Monitoring Stroomgebieden (monitoring drainage basins), which is financed by the ministries of LNV, VROM and V&W, an intensive monitoring programme has been established for a peat area (Krimpernerwaard), a clay area (Quarles van Uffort), a highly loaded sandy area (Schuitenbeek) and a low loaded sandy area (Drentse Aa). In all of these areas, the diffuse impact on the surface water due to agriculture is shown to be the main source of phosphate (Leenders *et al.*, 2007).

Therefore, phosphate saturated soils form a relevant source for the leaching of phosphate to the surface water. The relationship between the degree of phosphate saturation of the soil and the leaching of phosphate to the surface water is however very complex. A multiplicity of factors determines the final transport of phosphate from the soil to the surface water (Schoumans *et al.*, in preparation). As a result, there are major regional differences. Phosphate leaking to the surface water mainly occurs from phosphate saturated parcels of land that are directly situated near watercourses and where relatively high groundwater levels occur throughout the course of the year. In addition, situations that experience a precipitation intensity that exceeds the infiltration capacity of the soil show an additional phosphate load in the surface water because puddles are first formed and then the water is drained away at ground level.

To drive back the eutrophication of the surface water, a substantial reduction in the supply of phosphate to the surface water is required (MNP, 2005). Source measures, targeted at reducing the supply of phosphate to the soil are therefore important in order to structurally drive back phosphate emissions to the surface water. However, if only source measures are employed, it can take several years to decades before any effect on the quality of the surface water is noticeable locally. Effect-targeted measures at the level of the parcel of land, that reduce the removal via *runoff* just after fertilisation or that change the drainage, can locally and in the short term give impressive results.

The normative and spatial details of the WFD will determine the size of the task for the agricultural sector. This will be influenced by the degree to which the WFD standards will relate to all surface waters, or will mainly be determined for the 'large areas of' surface waters (such as rivers and lakes). It is mainly the ‘small areas of’ surface water (such as ditches, also referred to in the Netherlands as '*landbouwwater* - agricultural water') that is directly influenced by agriculture.

It is recommended to develop measuring methods and to apply them in characteristic regions to distinguish the influence of various sources, in order to identify the correct source-targeted and effect-targeted measures. In addition to developing a model of the behaviour of phosphate in the soil, it is recommended to quantify the relationship between phosphate in agriculture and phosphate in surface water via targeted measurements.

Question 3
Under which circumstances is phosphate extraction an effective method of remediating phosphate saturated soils or combating phosphate leaking?

Phosphate extraction is the action of reducing the phosphate status and the level of phosphate in the soil by growing and removing a crop using no or very low levels of phosphate fertilisation. Phosphate extraction can relatively quickly reduce the phosphate status in the top approximately 20 centimetres of the soil, as a crop is easily capable of extracting the directly available ('unstable') mineral phosphate fraction from the soil. Phosphate extraction results in a relatively large drop in the phosphate concentration in the soil solution, causing leaching to decrease markedly. This applies in particular to grassland, as between 70 to 130 kg of phosphate per ha per year is removed with the harvested grass. With other crops, between 40 and 60 kg of phosphate per ha per year is removed (Ehlert *et al.*, 2006). Without phosphate fertilisation, an amount of phosphate can be removed with the crop annually that is equal to the amount of phosphate that would be supplied if balanced fertilisation were adhered to. In situations in which shallow phosphate leaching via the soil to the surface water is the main leaching route, reduction of the phosphate status of the top layer of soil through phosphate extraction leads to a lower impact on the surface water. Here phosphate extraction is an effective means of reducing the phosphate load in the surface water.

There are also situations in which phosphate extraction does not reduce the amount of easily available phosphate by more than would be the case if balanced fertilisation were used (Reijneveld *et al*., 2003). In six years of using respectively no fertilisation, balanced fertilisation and half of the amount associated with balanced fertilisation at 'De Marke', no significant difference was found in the change of the Pw value between the various treatments. It is reasonable to interpret the Pw value as easily available phosphate. This means that the amount of easily available phosphate in the soil was not lower when no fertilisation was applied than when the principles of balanced fertilisation were applied. This can be the result of the fact that the experiment took place on a parcel of land where after three years grassland mangel-wurzel was grown for one year followed by two years of maize. Crop rotation can have the effect of increasing the Pw in spite of extraction, and can have changed the ratio between the amounts of inorganic and organic phosphate. In the agricultural sense this is favourable, as the crop yield will not be rapidly limited by a lack of phosphate in spite of no or a low P fertilisation. In the environmental sense this effect of crop rotation can also be favourable, as a high P removal in case of phosphate extraction can be retained, which increases the speed of phosphate extraction. In situations where there is a high risk of leaching, maintaining a stable Pw by crop rotation might be unfavourable, assuming that there is a relationship between the Pw value, the concentration of P in solution, and the leaching of P to the surface water.

The more the soil is saturated with phosphate, the longer the period of phosphate extraction. The more the phosphate is also present deeper in the soil, under the root zone, the less effective phosphate extraction will be. Up to 10,000 kg of phosphate per ha has accumulated in some phosphate saturated soils and in this situation it will take many decades to completely remediate the soil. Therefore phosphate extraction in these situations requires a lot of perseverance.

Phosphate extraction offers opportunities for the transition from intensively managed agricultural land to a herb-rich grassland, in particular because phosphate extraction not only reduces the phosphate level but also the amount of nitrogen available in the soil. However, in most cases the measure is insufficient to transform agricultural land into low nutrient grasslands with a high degree of biodiversity and therefore a high nature value. The required reduction of the level of phosphate in the soil to a level in which phosphate limitation can lead to this species-rich low nutrient grassland is such that phosphate extraction used as the only measure will take a very long time (in the order of hundreds of years).

Another method used to combat phosphate leaching from the soil is to apply minerals that contain iron and/or aluminium that naturally bind to phosphate. Field experiments were carried out in, among others, the United States (aluminium sulphate) and Australia (zeolites). A number of materials have been tested in the circumstances found in the Netherlands (Schoumans and Köhlenberg, 1995; Schoumans and van der Molen, 1995; Kronvang *et al.*, 2005). The TCB argues for cautionary approach to be taken with respect to the application of phosphate-binding substances in the Netherlands. It is an effect-targeted *end-of-pipe* measure, mainly suitable if all other measures fail.

CONCLUSIONS

The TCB recommends that the phosphate application standards be differentiated into three classes based on the phosphate status of the soil, and when making the differentiation to use the principles of the fertiliser recommendations. This differentiation must still be worked out in more detail. Differentiation according to this system leads to phosphate being extracted from phosphate saturated soils. The approach to phosphate saturated soils can only then be successful if at the same time the to be expected non-processable 'manure surplus' will be driven back.

Phosphate saturated soils form a relevant source of phosphate leaching to the groundwater and surface water. The actual leaking of phosphate from the soil to the surface water is not only determined by the phosphate status of the soil, but also and mainly by the hydrological circumstances and the position of the parcel of land in relationship to the local surface water. This makes it a complex process. There are indications that the surface runoff of fertiliser (over the surface and through the upper layer of the soil), rather rapidly after supplying the fertiliser, contributes significantly to the local eutrophication of the surface water.

By employing phosphate extraction, every year a proportion of the total buffer of phosphate present in the top soil can be removed. The TCB considers phosphate extraction to be an effective method to relatively quickly lower the phosphate status of the cultivated soil and with it to reduce the chance of leaching to the surface water. The full remediation of phosphate saturated soil by phosphate extraction will in most cases take hundreds of years.

LITERATURE

Bakker, D.W. en A.C.C. Plette, 2007. Mest en Oppervlaktewater. Een terugblik 1985-2005. Deelrapport ten behoeve van de evaluatie meststoffenwet 2007. RIZA rapport 2007.

Beek, C.L. van, 2007. Nutrient losses from grassland on peat soils. Proefschrift Wageningen Universiteit, 109 pp.

Berge ten H.F.M., A.M. van Dam, B.H. Janssen en G.L. Velthof, 2007. Mestbeleid en bodemvruchtbaarheid in de Duin- en Bollenstreek WOT-werkdocument, Wageningen.

Breeuwsma, A. en O.F. Schoumans, 1986. Fosfaatophoping en –uitspoeling in de bodem van mestoverschotgebieden. Stiboka rapport nr. 1866, 66 pp.

Brookes P.C., G. Heckrath, J. de Smet, G. Hofman, J.Vanderdeelen, 1997. Losses of phosphorus in drainage water. In: H. Tunney, O.T. Carton, P.C. Brookes, A.E. Johston, 1997. Phosphorus loss from soil to water. CAB International, p 253-271.

Commissie Bemesting Grasland en Voedergewassen 2007. Adviesbasis bemesting grasland en voedergewassen (http://www.bemestingsadvies.nl/).

Dam, A.M. van, L.J.M. Kater en N.S. van Wees, 2004. Adviesbasis voor de bemesting van Bloembolgewassen. Publicatie 708. Praktijkonderzoek Plant & Omgeving, Lisse.

Dawson C.J. and A.E. Johnston 2006 Agricultural phosphorus in relations to its effect on water quality. IFS proceedings no 589.

Dijk W. van, J.G. Conijn, J.F.M. Huijsmans, J.C. Middelkoop en K.B. Zwart, 2003. Adviesbasis voor de bemesting van akkerbouw- en vollegrondsgroentegewassen. Publicatie 307. Praktijkonderzoek Plant & Omgeving, Lelystad.

Eertwegh, G.A.P.H. en C.L. van Beek, 2004. Water- en Nutriënthuishouding van een veenweidegebied. De vlietpolder in Zuid-holland in beeld. STOWA-rapport 2004-30.

Ehlert, P.A.I., J.C. van Middelkoop en P.H.M. Dekker, 2006. Fosfaatafvoer en fosfaatgehalten van landbouwgewassen. Alterra Rapport 1348, Wageningen, 92 pp.

Esperschütz, J., A. Gattinger, P. Mäder, M. Schloter and A. Flieβbach, 2007. Response of soil microbial biomass and community structures to conventional and organic farming systems under identical crop rotations. FEMS Microbiology Ecology 61, 26–37.

Ham, A. van den, C.H.G. Daatselaar, G.J. Doornewaard & D.W. de Hoop, in voorbereiding. Bodemoverschotten op landbouwbedrijven. Deelrapportage van Ex Post Milieukwaliteit; studie in het kader van de Evaluatie Meststoffenwet 2007 (EMW 2007).

Hamel, C. 2004. Impact of arbuscular mycorrhizal fungi on N and P cycling in the root zone. Canadian Journal of Soil Science 84: 383–395.

Haygarth, P.M and Jarvis S.C. (eds.), 2002. Agriculture, Hydrology and Water Quality. Cabi Publishing, Wallingford, UK, 502 pp.

Henkens, Ch.H., 1969. Problemen rond de organische mest. De Bedrijfspluimveehouder 47:689.

Houba, V.J.G. and E.J.M. Temminghof, 1999. Behaviour of phosphate in soil extracts using weakly buffered extracting solutions. Communications in Soil Science and Plant Analysis 30: 1367-1370.

Johansson, J.F., L.R. Paul and R.D. Finlay, 2004. Microbial interactions in the mycorrhizosphere and their significance for sustainable agriculture. FEMS Microbiology Ecology 48, 1-13.

Koopmans, G.F., 2004. Characterisation, desorption, and mining of phosphorus in noncalcareaous sandy soils. Proefschrift, Wageningen Universiteit.

Korevaar, H., A. van der Werf, R.H.E.M. Geerts & W. de Visser. 2006. Long-term effects of nutrients on productivity and species-richness of grasslands: the Ossenkampen fertilizer experiment. Poster abstract in: Long-term studies in ecology, A celebration of 150 years of the Park Grass Experiment. Harpenden, UK.

Kronvang, B., M. Bechmann, H. Lundekvam, H. Behrendt, G.H. Rubaek, O.F. Schoumans, N. Syversen, H.E. Andersen and C.C. Hoffmann, 2005. Phosphorus losses from agricultural areas in river basins; effects and uncertainties of targeted mitigation measures. Journal of Environmental Quality 34 (2005).pp. 2129 – 2144.

Laegreid, M., O.C. Bockman and E.O. Kaarstad, 1999. Agriculture, Fertilizers and the Environment. CABI Publishing in association with Norsk Hydro ASA, Wallingford, UK.

Lande Cremer, L.C.N. de la, 1970. Mestoverschotten, een potentiële bron van milieuverontreiniging. Kali 80: 361-368.

Leenders, T.P, J. Roelsma, F.J.E. van der Bolt, O.F. Schoumans, H.C. Jansen, J.G. Kroes, 2007. Nutriëntenbelasting van het landsysteem op het oppervlaktewater in relatie tot de oppervlaktewaterkwaliteit in vier stroormgebieden; Bijdrage aan de Evaluatie Meststoffenwet 2007 ex-post milieukwaliteit. Alterra rapport 1477, Wageningen, 98 pp.

Luesink H.H., in voorbereiding. Monitoring mestmarkt 2006. Rapportages LEI en WUR.

Mäder, P., A. Fliessbach, D. Dubois, L. Gunst, P. Fried and U. Niggli, 2002. Soil Fertility and Biodiversity in Organic Farming. Science 296, 1694-1697.

MNP, 2004. Mineralen beter geregeld. Evaluatie van de werking van de Meststoffenwet 1998-2003. MNP en RIVM. Rapport nr. 500031001, RIVM, Bilthoven.

MNP, 2005. Milieukwaliteit en verliesnormen, Deelproject 1 van de Evaluatie Meststoffenwet 2004. MNP en RIVM. RIVM rapport nr 50031002/2005.

Neeteson J., J. Schröder, B. Smit, J Bos and K. Verloop, 2006. Need and opportunities to reduce phosphorus inputs, soil supply and loss from agriculture in the Netherlands, IFS proceedings no. 595.

Noordwijk, M. van, P. de Willigen, P.A.E. Ehlert and W.J. Chardon, 1990. A simple model of P uptake by crops as a possible basis for P fertilizer recommendations. Neth. J. Agric. Science 38: 317-332.

Reijneveld, J.A., J. Verloop en G.J. Hilhorst, 2003. Sanering van zandgrond met een hoge fosfaattoestand; resultaten van een veldexperiment op proefbedrijf de Marke. De Marke rapport 43.

Reijneveld, J.A., J. van Wensem and O. Oenema, in review. Trends in soil organic carbon contents of agricultural land in the Netherlands between 1984 and 2004.

Rotterdam-Los A.M.D. van, E.J.M. Temminghoff, W. Busink, W.H. van Riemsdijk (in voorbereiding). Predicting phosphorus desorption kinetics based on a combination of two standard soil tests.

Salm, C. van der, J. Dolfing, J.W. van Groenigen, M. Heinen, G. Koopmans, J. Oenema, M. Pleijter en A. van den Toorn, 2006. Diffuse belasting van het oppervlaktewater met nutriënten vanuit grasland op een zware kleigrond. Monitoring van nutriëntenemissies op een melkveehouderijbedrijf in Waardenburg. STOWA-rapport 2006-12.

Schoumans, O.F., A. Breeuwsma, A. El Bachrioui-Louwerse en R. Zwijnen, 1991. De relatie tussen de bodemvruchtbaarheidsparameters Pw- en P-Al-getal, en fosfaatverzadiging bij zandgronden. Rapport 112, DLO-Staring Centrum, Wageningen, 1991.

Schoumans, O.F. en H. Köhlenberg, 1995. Onderzoek naar maatregelen ter vermindering van de fosfaatuitspoeling uit landbouwgronden. Mogelijkheden van toediening van aluminium en ijzerverbindingen aan de bodem. Staring Centrum Wageningen, Rapport no. 374.

Schoumans, O.F. en R. Kruijne, 1995a. Onderzoek naar maatregelen ter vermindering van de fosfaatuitspoeling uit landbouwgronden. Meting van de fosfaatuitspoeling uit fosfaatverzadigde zandgrond met en zonder hydrologische maatregel. Staring Centrum Wageningen, Rapport no. 374.1.

Schoumans, O.F. en R. Kruijne, 1995b. Voorspelling van de fosfaatuitspoeling naar het oppervlaktewater in het stroomgebied van de Schuitenbeek. Staring Centrum Wageningen, Rapport no. 386.

Schoumans, O.F., R. Kruijne en D.T. van der Molen, 1995. Vermindering van de fosfaatuitspoeling. Mogelijkheden bij fosfaatverzadigde gronden. Landschap. Vol. 6: 63-73.

Schoumans, O.F. en P. Lepelaar, 1995. Emissie van bestrijdingsmiddelen en nutriënten in de bloembollenteelt. Procesbeschrijving van het gedrag van anorganisch fosfaat in kalkrijke zandgronden. Rapport 387,1. Alterra, Wageningen.

Schoumans, O.F. en P. Groenendijk, 2000. Modeling soil phosphorus levels and phosphorus leaching from agricultural land in the Netherlands. J. environ. Qual. 29 (2000), 1: 111-116.

Schoumans, O.F., J. Roelsma, H.P.Oosterom, P. Groenendijk, H. Van Zeijts, G.J. van der Born, S. van Tol, H.F.M. van den Berg, H.G. van der Meer en F.K. Evert, 2002. Nutriëntenemissies vanuit landbouwgronden naar het grondwater en oppervlaktewater bij varianten van verliesnormen. Modelberekeningen met STONE 2,0. Clusterrapport 4: deel 1. Alterra, Wageningen.

Schoumans, O.F., 2004. Inventarisatie van de fosfaatverzadiging van landbouwgronden in Nederland. Alterra rapport 730,4. Alterra, Wageningen. In het kader van de Evaluatie Meststoffenwet 2004.

Schoumans, O.F., P.A.I. Ehlert, W.J. Chardon, 2004a. Evaluatie van methoden voor de karakterisering van gronden die in aanmerking komen voor reparatiebemesting. Alterra rapport 730,3. Alterra, Wageningen. In het kader van de Evaluatie Meststoffenwet 2004.

Schoumans, O.F., L. Renaud, H. Oosterom, P. Groenendijk, 2004b. Lot van het fosfaatoverschot. Analyse van STONE-berekeningen die zijn uitgevoerd in het kader van de Evaluatie Meststoffenwet 2004. Alterra rapport 730,5. Alterra, Wageningen. In het kader van de Evaluatie Meststoffenwet.

Schoumans, O.F., 2007a. trends in de fosfaattoestand van landbouwgronden in Nederland in de periode 1998-2003. Rapportage in het kader van de Evaluatie Meststoffenwet 2007. Alterra rapport.

Schoumans, O.F., 2007b. Phosphorus Regulations in Europe. Outcome of an inventory in 27 countries involved in EU-COST action 869. "Mitigation Options for Nutrient Reduction in Surface Water and Ground water *at River Basin Scale in order to Reach Targets of the Water Framework Directive"*. Oral Presentation and draft report, Working Group Meeting in Hamar (No) 22 May - 25 May 2007.

Schoumans, O.F., P. Groenendijk, C. van der Salm en M. Pleijter, in voorbereiding. Methodiek voor het karakteriseren van fosfaatlekkende gronde. PLEASE. Alterra rapport, Wageningen.

Smolders, A., E. Lucassen E., H. Tomassen, L. Lamers en J. Roelofs, 2006. De problematiek van fosfaat voor natuurbeheer. Vakblad natuur, bos en landschap, april 2006 p 5-11.

TCB, 1990. Advies parameters ten behoeve van het protocol fosfaatverzadigde gronden. S/90-09. 6 maart 1990.

Torenbeek, R., 2003. Diffuse belasting van oppervlaktewater met nutriënten in de veehouderij (DOVE). Grasland op zand. STOWA-rapport 2003-16.

Van de Weerd, H. en R. Torenbeek, 2007. Uitspoeling van meststoffen uit graslanden – emissieroutes onder de loep. STOWA-publicatie, in voorbereiding.

VLM, 1997. Fosfaatverzadiging van zandige bodems in Vlaanderen. VLM, Brussel, 143 p.

Vries F.T. de, E. Hoffland, N. Van Eekeren, L. Brussaard and J. Bloem, 2006. Fungal/bacterial ratios in grasslands with contrasting management. Soil Biology and Biochemistry 38, 2092-2103.

Wal A. van de, J.A. van Veen, W. Smant, H.T.S. Boschker, J. Bloem, P. Kardol, W.H. van der Putten and W. de Boer, 2006. Fungal biomass development in a chronosequence of land abandonment. Soil Biology and Biochemistry 38, 51-60.

Wassen, M.J., H. Olde Venterink, E.D. Lapshina en F. Tanneberger, 2005. Endangered plants persists under phosphorus limitation. Nature 437, 547-550.