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CONTRIBUTION OF AGRICULTURE TO EUTROPHICATION OF SURFACE WATERS WITH NITROGEN AND PHOSPHORUS IN THE NETHERLANDS

by

G. J. Kolenbrander

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CONTENTS

I. INTRODUCTION

In his excellent report on scientific fundamentals of eutrophication Vollenweider (1968) states that: "the eutrophication of waters, which means their enrichment in nutrients and the ensuing progressive deterioration of their quality, especially lakes, due to the luxuriant growth of plants with its repercussions on the overall metabolism of the waters affected, is a problem of increasing urgency in the more highly developed countries".

This statement applies also to the Netherlands, but especially to the new lakes, created within the frame work of the deltaproject that is intended to control the total water management in the Netherlands.

Eutrophication is not a new problem. Already in antiquity Augias cleaned his stable by means of a stream. And around 1800 the farmers in the north of Groningen used their stable manure only "to fill up ditches and pits because they considered manure as unprofitable rubbish" (Honderd Jaar Plattelandsleven in Groningen 1952). But op to the present a great deal of urine and drainage water from dung heaps has been running into ditches in the western part of the Netherlands, where the peat layer has a depth of 15 m, which makes the construction of liquid manure tanks uneconomical.

Among the nutrients responsible for eutrophication, nitrogen and phosphorus have been found to be the most important elements. The general view is that phosphorus is the causal factor in eutrophication. However, Legg and Dingeldein (1970) are of the opinion that not phosphorus but carbonaceous material is the dominant factor in the process.

We shall not enter into this question, which is a problem of limnologists, but consider the role of agriculture in the enrichment of surface waters with nitrogen and phosphorus.

II. CONTRIBUTION OF AGRICULTURE TO EUTROPHICATION

In agriculture we can distinguish three sources which may contribute to eutrophication of surface waters.

1. Leaching.
2. Surface run-off and erosion.
3. Direct pollution with animal waste and fertilizers.

1. Leaching

Leaching can be studied in two manners:
(A) movement studies in a profile (indirect method),
(B) lysimeter studies (direct method).

A. Movement studies in a profile

a. Nitrogen. Of the different nitrogen forms (org. N, NH_4-N, NO_3-N) nitrate-nitrogen is highly soluble in water and is not adsorbed by the organic matter or soil particles. In addition, NH_4-N, which is strongly bound, is oxidized rapidly to nitrate by microbial activity. The organic nitrogen in the soil is mostly insoluble in water and has to be mineralized and oxidized before the nitrogen becomes mobile.

The origin of high nitrate concentrations in ground-water can be very different and ranges from leakage from septic and liquid manure tanks to leaching of mineral nitrogen from soil. Thus Trines (1952) found in the southern part of the Netherlands in private wells on sandy soils concentrations of up to 300 mg N/l. However, 40-50% of the samples contained B. Coli Escherichia, which is an indication of recent fecal pollution. In the remaining cases leaching from the soil is likely the main cause of the high nitrate content. Also Stout and Burau (1967) draw the conclusion from their study of deep profiles(up to 15 m) that the soil fertility level is the main factor determining the concentrations of nitrate that can exist below root zones both under cultivated and non-cultivated circumstances. It became apparent from this study that any fertile sandy soil has an inherent potential nitrate supplying power which may contribute about 22.5 ppm N (= 100 ppm NO_3). This is the maximum concentration allowed in drinking water in the Netherlands. Soils of low fertility tend to transport less nitrate to ground-water. The nitrate concentrations are reduced again directly in proportion to the fraction of applied water that passes through the profile.

The results of Stout and Burau (1967) make it clear that the use of artificial fertilizers is not necessarily the direct cause of high nitrate concentrations in ground-water. This is also evident from experiments of Headden (1910) who found high nitrate levels in ground water at a time when fertilization practices contributed insignificant amounts.
Regarding the nitrate level in deep ground-water (25-125 m) under Pleistocene sandy soils, as used by 22 water supply companies in the Netherlands, Kolenbrander (1970) found in 33% of the water works a small increase in nitrate content (0.57 mg N/l = 2.5 mg NO_3/l) over the period 1920-1970, but in 66% of the water works there was not any change and the content of the raw water was still zero. It was not possible to establish with certainty that a relation existed between fertilizer practices and the small increase in nitrate content.

The low content of this raw water (0-4.5 mg N/l) in relation to the concentration in a profile (Stout and Burau 1967) suggests that denitrification takes place in the subsoil during downward movement.

b. Phosphorus. In contrast with nitrate, inorganic phosphorus easily forms "insoluble" compounds with Ca-, Fe- and Al-ions. All these ions are found in varying amounts in sandy and clay soils.

Fixation of phosphate by these ions results in a low P-concentration and slow downward movement in the profile. It is conceivable that after prolonged fertilization the fixing capacity of the upper layer is saturated and that leaching of phosphorus to the subsoil starts. However, the subsoil may have also a great P-fixing-capacity which keeps the phosphorus concentration and the leaching loss low. That does not alter the fact that time will be an important factor in this downward transport of phosphorus, and that this movement should be studied in long-term experiments. Such experiments are, however, rare.

In the Maschhaupt lysimeter (1941), filled with a marine silty clay loam (23% <16 μ), cropped, and fertilized with 25 kg P/ha/y during 40 years, the phosphorus penetrated to 5 cm below the topsoil.

Two cropped phosphorus field experiments on sandy soil show a penetration depth of 15-20 cm below the top soil after application of 44-88 kg P/ha/y as superphosphate for 14-18 years. In our 10-year old grassland lysimeter, also filled with a sandy soil and fertilized with 75 kg P/ha/y, the phosphorus had penetrated to a depth of 10 cm after 10 years. Cooke and Williams (1970) published results showing that after 100 years the phosphorus had penetrated to a depth of 40 cm in the Barnfield and to 50 cm in the Parkgrass experiment.

Table 1 summarizes these results assuming that the topsoil on arable land has a thickness of 20 cm.

TABLE 1. Penetration velocity of fertilizer phosphorus in different soils

	Sandy soil	Clay soil
arable land (below top-soil)	1.1 cm/y	0.1-0.2 cm/y
grassland (sod included)	1.0 cm/y	0.5 cm/y

We have to realize that the penetration depth on cropped land not only depends on vertical water transport. The rooting depth is also an important factor, as the roots transport phosphorus from the topsoil to the subsoil. Which of the two factors has the greater effect is not known and therefore it is not possible to conclude from table 1 that the depth of penetration in a sandy soil after 100 years will be 100 cm (below the top-soil). It may be considerably less!

The velocity of penetration also depends on the type of phosphorus compound. Ordinary fertilizer releases the phosphorus in a form which can be adsorbed very fast. However, when phosphorus is applied in slurry or sewage water from dairy and potato industries the adsorption of the water-soluble P contained in organic compounds will be very small. After mineralization in the root zone there will be no problem, but high rainfall shortly after manuring may intensify the downward transport. Perhaps the chance of high rainfall after application will be very small in a given year, but nevertheless after a number of years the possibility of an increased phosphorus content of the sub-soil is real.

Irrigation with high amounts of waste water will saturate the soil during a long period and therefore increase the downward movement of water and salts. Thus Rietz (1969) found in a lysimeter study that at a depth of 40 cm the P content of applied sewage water from a potato-starch factory was reduced from 53 to 9 mg P/l. Van Geneygen and Scheltinga (1970) found for sewage water from a dairy applied to a lysimeter of 60 cm depth a reduction from 9.4 mg P/l to about 2.6 mg P/l.

However, even this strong reduction in phosphorus content of the irrigation water is insufficient to prevent an enrichment of the sub-soil below the root zone.

Van Geneygen and de la Lande Cremer (1971, yet unpublished) applied in an experiment on sandy soil 8 portions of 30 ton/ha of swine manure in slurry form within a few weeks.

Within a year they found under normal weather conditions an increase in total phosphorus content to a depth of 100 cm!

All these results ask for our attention as they indicate that on sandy soils the possibility of pollution of the deeper layers cannot be excluded. Such pollution can become a cause of increased phosphorus concentrations of ground and surface water.

B. Lysimeter studies

The lysimeter technique opens the possibility to study the losses by leaching in a direct way. However, 50 years of hydrological research in the Netherlands has resulted in only 3 lysimeter experiments in which also leaching losses were studied. This is a poor result in view of the great number of factors influencing leaching losses. Therefore, Kolenbrander (1969) analysed the results of a great number of lysimeter experiments published in the literature. In addition to the amount of drainage water, also the type of crop, the nature of the soil, the amount of fertilizer and the time of application are important factors.

a. Nitrogen. (1) <u>N-losses from soil and fertilizer.</u> The N-losses from soil and fertilizer on arable and grassland have been calculated by Kolenbrander (1969) for an annual amount of drainage water of 350 mm and a profile depth of 100 cm. Results obtained by Wind (1960) indicate that 300 mm/year would be a better mean value for the Netherlands. The results for 300 mm can be calculated easily from those for 350 mm by multiplying by 300/350 = 0.856. In this way we find from results of Kolenbrander (1969) that the annual nitrogen loss by leaching on an unfertilised arable sandy soil is about 50 kg N/ha and on a clay soil 20 kg N/ha, both on the basis of 300 mm drainage water and 1 m depth. For grassland a value of about 7 kg N/ha/y was found.

The amount of nitrogen fertilizer used in the Netherlands is about 100 kg N/ha/y on arable land and about 225 kg N/ha/y on grassland. From the results of Kolenbrander (1969) we can estimate again that the leaching loss of nitrogen on arable land will be increased by this rate of fertilizer application by about 17 kg N/ha on cropped sandy soils, by about 4 kg N/ha/y on cropped clay soils (14-40% $<16\mu$) and by 2 kg N/ha/y on grassland.

The great difference in leaching loss between cropped, sandy and clay soils is striking. From figure 1 we can see that the recovery by plants of fertilizer nitrogen on arable land with different clay content is about the same, viz. 50%. Hence the great difference in leaching loss on arable land must be principally caused by a difference in the rate of denitrification. The latter is related to the difference in pore-size distribution between sandy and clay soils. Due to their greater number of small pores, clay soils will be more subject to anaerobic conditions than sandy soils.

(2) N-losses from organic manure. In addition to fertilizer nitrogen, about 100 kg total nitrogen /ha is applied as farmyard manure and urine or slurry. The fertilizer nitrogen is applied only in the growing season but organic manure also in autumn and winter because the storage capacity is mostly too small. We will assume that 50% is used in autumn and winter and 50% in spring and summer. 100 kg of N in slurry, applied in spring and summer, is equivalent to 50 kg fertilizer N as assessed by dry-matter production on arable land and equivalent to 35 kg fertilizer N in grassland. In the case of autumn and winter applications the effect is smaller due to leaching and is equivalent to 37.5 kg of fertilizer N on arable land and 27.5 kg N on grassland (Kolenbrander en De la Lande Cremer 1967). We will assume further that in spring the plant-available nitrogen in organic manure will be subject to the same leaching losses as Kolenbrander (1969) calculated for fertilizer nitrogen at this low level of about 20 kg N/ha.

Thus we arrive at the results of table 2 from which it is apparent that the annual leaching losses per 100 kg total nitrogen in slurry are 8 kg N/ha on arable land and 4 kg N/ha on grassland.

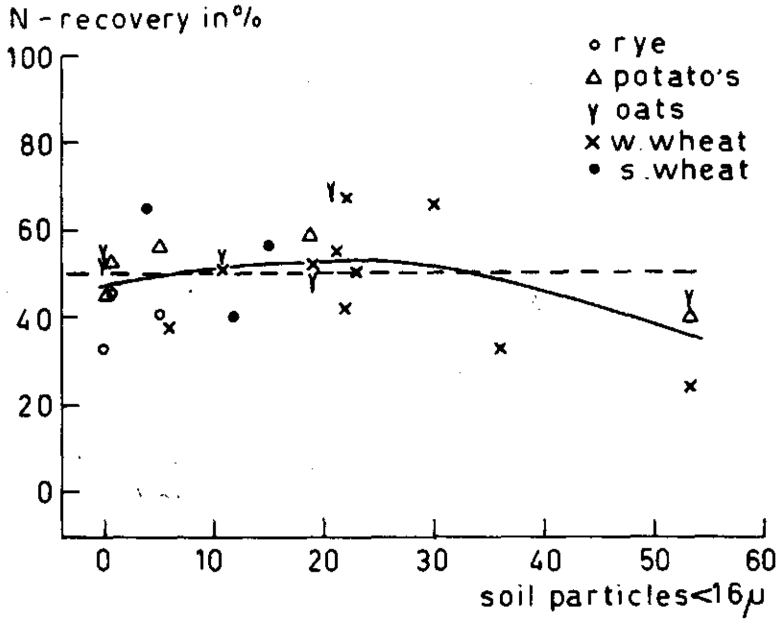

Fig. 1 Relation between the recovery of N-fertilizer and the clay content of the soil. (experiments of Van Burg, Dilz and Van der Paauw).

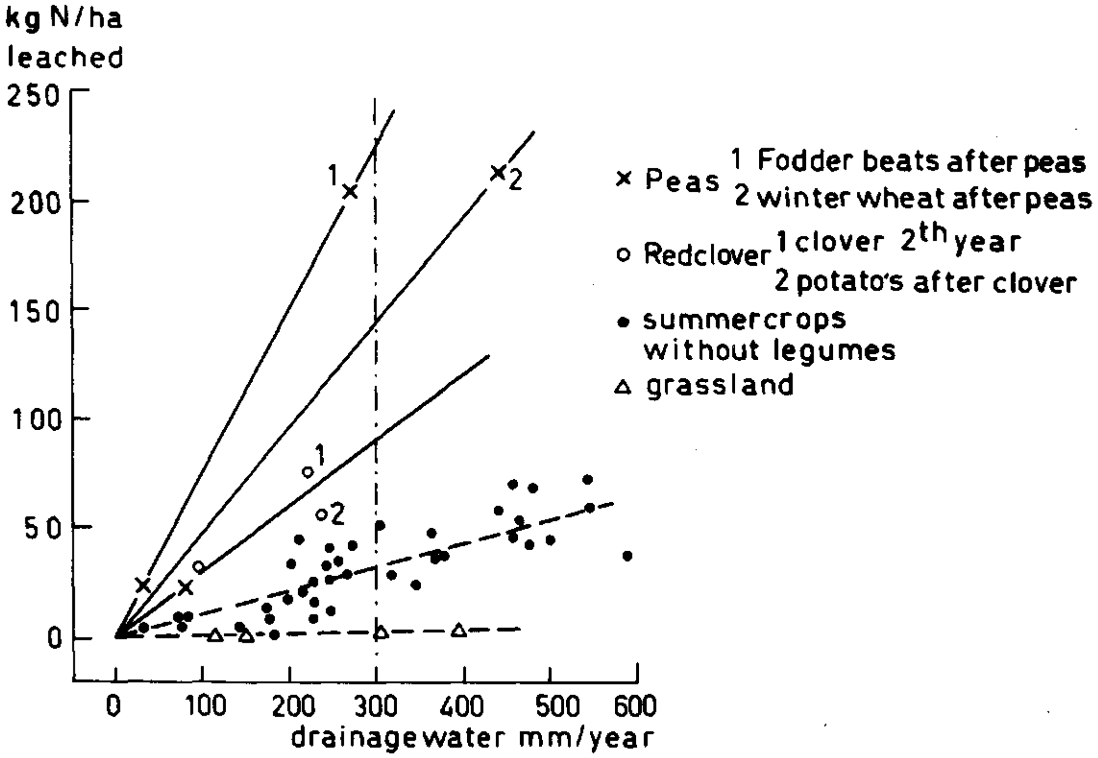

Fig. 2 Leaching losses of nitrogen with and without legumes (Maschhaupt 1941)

TABLE 2 The annually applied, available and leached nitrogen originating from slurry applied to arable land and grassland on sandy soils (kg N/ha/y)

	Arable land		Grassland	
	spring	autumn	spring	autumn
N-applied	50	50	50	50
leached in winter	-	6	-	4
available in spring	25	19	18	14
leached in summer	1	1	0	0
total leached	8		4	

We assume that also in this case the leaching losses from clay soils are smaller than from sandy soils (20/50 x 8 = 3 kg N/ha/y). For grassland this effect is so small that it will be neglected.

(3) N-losses from leguminous plants. The effect of legumes on leaching losses of nitrogen is also very important as shown by lysimeter results of Maschhaupt (1941) in figure 2. It should be noted that Maschhaupt calculated the annual drainage water production and the nitrogen losses from 1 september - 1 september.

From figure 2 its is apparent that with spring-sown crops, legumes excluded, the annual nitrogen loss through leaching is about 32 kg N/ha with 300 mm drainage water. Under a 2 year-old crop of red clever and in the potato year, after plowing-under the clover in November, the nitrogen loss is about 90 kg N/ha which means an extra N-loss of about 60 kg N/ha.

However, after peas, harvested in the beginning of August, the nitrogen loss through leaching is still much higher. When the soil remained fallow after harvesting the peas (next crop mangolds), the loss was 225 kg N/ha. When winter wheat was sown in autumn still 145 kg N/ha was lost. The mean extra loss is here about 150 kg N/ha.

From these results it becomes clear that a large part of the biologically-fixed nitrogen in the root nodules of the pulse crops and legumes is not used by the next crop, also when a catch crop is sown in autumn.

The presence of legumes in a rotation will result in an increased N-loss through leaching. In this respect grass as green manure crop should be preferred. Figure 2 shows that with grass the annual N-loss is small (approx. 4 kg N/ha). But also after breaking-up the sod Maschhaupt obtained quite normal N-losses during the next two years with oats and potatoes.

However, the area of pulse crops and legumes is relatively small in the Netherlands. In 1966 there was about 20,000 ha of pulse crops and 8,000 ha of legumes. Since these crops are grown mainly on clay soils we can make the following calculation (table 3).

TABLE 3. The contribution of leguminous plants to leaching losses of nitrogen on clay soils in the Netherlands per 100 ha arable land

	Area, ha	N-loss, kg N/ha	Total loss kg N
without legumes	93	20	1860
pulse crops	5	170*	850
legumes	2	80**	160
total	100		2870

* 20 + 150 = 170 kg N/ha　　** 20 + 60 = 80 kg N/ha

The mean loss, including leguminous plants, is about 29 kg N/ha/y, and without leguminous plants about 20 kg N/ha/y. So the mean contribution of leguminous plants per ha is about 9 kg N/ha/y on clay soils.

(4) The mean total N-losses through leaching. In table 4 the different results are summarized for mineral soils only, as for peat soils no leaching results are available. From this table it becomes clear that the mean nitrogen loss through

leaching is about 29 kg N/ha/year. But it is striking that 62% of this loss is already found in unfertilized soil. This nitrogen originates from the large nitrogen stock in the soil, (a soil with 4% organic matter and a C/N ratio of 12. containes about 5,600 kg N/ha in the topsoil) part of which is mineralized by microbial activity. The real leaching loss from this N-stock is very small, viz. about 0.3%/ha/y.

Of the mean total loss, 17% originates from fertilizer-N, but here also the real leaching loss is small because out of 175 kg N/ha, only 5 kg N/ha is washed out, or 2.2%.

Table 4 shows also that the highest N-leaching losses are found on arable sandy soils. The texture of these soils allows rapid downward movement of the nitrogen, mineralized from the root residues after harvest, in autumn and winter, while the loss by denitrification will be minimal.

The lowest N-leaching losses are found in grassland in spite of the high fertilizer application. Here the fertilizer loss is about 1%. This is because of the high rate of N-uptake and the long growing period of the grass, the absence of fallowing and the fact that the total amount is given in 4-6 split applications, which are given only during the growing season. Especially these conditions opened the possibility of increasing fertilizer use strongly without increasing the N-losses. If we assume that all the nitrogen leached deeper than 100 cm will contribute to eutrophication and that leaching loss from peat soils will be of the same order as on mineral soils, then from table 4 we can estimate the total contribution of agriculture to eutrophication through leaching of nitrogen.

For 775,000 ha arable land the contribution can be estimated at 42×10^6 kg N, for 1,350,000 ha grassland at 17×10^6 kg N, totaling 59×10^6 kg N, of which 62% arises from soil organic matter by microbial activity.

TABLE 4. Annual leaching loss of nitrogen from cropped fields in the Netherlands in kg N/ha when the drainage water is 300 mm/year

	Sandy soils	Clay soils	Total (weighted mean)	%
arable land	0.35×10^6 ha	0.41×10^6 ha	0.76×10^6 ha	
soil (unfertilized)	50 kg N/ha	20 kg N/ha	34 kg N/ha	63
fertilizer 100 kg N/ha	17 "	4 "	10 "	19
org. manure 100 kg N/ha	8 "	3 "	5 "	9
leguminous plants	- "	9 "	5 "	9
total	75 kg N/ha	36 kg N/ha	54 kg N/ha	100
grassland	0.75×10^6 ha	0.38×10^6 ha	1.13×10^6 ha	
soil (unfertilized)	7 kg N/ha	7 kg N/ha	7 kg N/ha	54
fertilizer 225 kg N/ha	2 "	2 "	2 "	15
org. manure 100 kg N/ha	4 "	4 "	4 "	31
total	13 kg N/ha	13 kg N/ha	13 kg N/ha	100
cultivated land	1.10×10^6 ha	0.79×10^6 ha	1.89×10^6 ha	
soil (unfertilized)	21 kg N/ha	14 kg N/ha	18 kg N/ha	62
fertilizer 175 kg N/ha	7 "	3 "	5 "	17
org. manure 100 kg N/ha	5 "	3 "	4 "	14
leguminous plants	- "	5 "	2 "	7
total	33 kg N/ha	25 kg N/ha	29 kg N/ha	100

b. Phosphorus. The losses of phosphorus in drainage water are mostly so small that different investigators have confined themselves to the remark "a trace". Figure 3 shows some results from Feilitzen et al. (1912), Gerlach (1926), Maschhaupt (1941), Geering (1943), Allison et al.(1959), Reys et al. (1961), Vömel (1965) and our own lysimeter experiments, where the loss of phosphorus was 0.57 kg P/ha/y at 625 mm of drainage water.

From these lysimeter results it becomes evident that the annual total loss of phosphorus from arable land is about 0.065 kg P/ha/y and from grassland 0.24 kg P/ha/y, when drainage amounts to 300 mm/y and assuming a lysimeter depth of about 1 m. Based on a ratio of arable land to grassland of 1:2 the mean leaching loss is about 0.18 kg P/ha/y (= 0.4 kg P_2O_5/ha/y). This is equivalent to a concentration in the drainage water of 0.06 mg P/l.

Minderman and Leeflang (1968) found a loss of 0.052 kg P/ha/y under a natural unfertilized dune sand vegetation.

The results of Low and Armitage (1970) for grassland are somewhat higher than found in figure 3. They calculated a loss of 0.870 kg P/ha/y at 215 mm drainage water. The results of Pfaff (1963) for clay soils, however, are far beyond this range. He found for a clay soil (30% $< 16\,\mu$) a loss of 2.00 kg P/ha/y at 215 mm and for a light clay soil (14% $< 16\,\mu$) 4.13 kg P/ha/y. However, such large differences may easily occur in lysimeter experiments. After we recently refilled a number of our lysimeters with a sandy soil containing 4% clay, we found that the drainage water contained 1 g/l clay particles. The total phosphorus content of the drainage water is 0.75 mg P/l with clay particles, but after separation in a high speed centrifuge the concentration is only 0.0087 mg P/l. It is evident that a large fraction of the total phosphorus is adsorbed on the clay particles, lost from the soil when the structure of the soil was destroyed by mixing before filling. Under natural circumstances however, this effect will be very small.

In contrast with nitrogen, no relation was found between the amount of P-fertilizer applied and the loss of P in the drainage water in these lysimeters with a depth of about 1 m. In view of the low phosphorus concentrations in soil moisture and the slow movement, such a relation can hardly be expected.

Only Wilson and Staker (1937) found an effect in a lysimeter (62.5 cm deep, and filled in with peat) after an application of 150 kg P/ha. However, the leaching rate of phosphorus in this experiment was already high without fertilizer, viz. 8.7 kg P/ha/y. It is possible that this is due to the "filling" effect. The mixing strongly stimulates mineralization of the soil organic matter. But also De Vries and Hetterschy (1936/37) calculated a loss of 7.8-15.7 kg P/ha/y for a 5-year-old, newly reclaimed peat soil.

We can check these results with the help of a great number of recent analyses of drainage water from different arable soils published by Henkens (1971).

Figure 4 shows the results. It is evident that the differences in total P-content of the drainage water from marine and fluvial clay soils, sandy soils and old reclaimed peat soils can be neglected. However, the newly reclaimed peat soils show also in this case a higher total P-content.

Assuming that after spring there will be again a decrease in concentration, we obtain the same picture for the P-concentration of the drainage water as Kolenbrander (1969) found for nitrogen.

An estimation of the mean production of drainage water in the different months gives us the possibility to calculate the losses in kg P/ha/y. For the mineral soils and the old reclaimed peat soils we find a loss of 0.085 kg P/ha/y, which is of the same order as found in figure 3 for arable land in lysimeters. The mean P-content in the period September-March was relatively constant on these soils and amounted to 0.0275 mg P/l.

On the newly reclaimed peat soils the calculated loss is 2.1 kg P/ha/y. This result is much lower than De Vries and Hetterschy (1936/37) obtained but it is still high compared with the other soils. The area of newly reclaimed peat soils, however, is small (about 23,000 ha, or 1% of our agricultural land). The total leaching losses for P can now be calculated as follows:

<u>arable land</u>	area	P-loss/ha/y	total P-loss
newly reclaimed peat soils	23,000 ha	2.13 kg	0.05x10^6 kg
remaining soils	752,000 ha	0.065 kg	0.05x10^6 kg
total	775,000 ha		0.10x10^6 kg
grassland	1,350,000 ha	0.24 kg	0.32x10^6 kg
total	2,125,000 ha		0.42x10^6 kg
This is a mean loss of			0.20 kg/ha/y

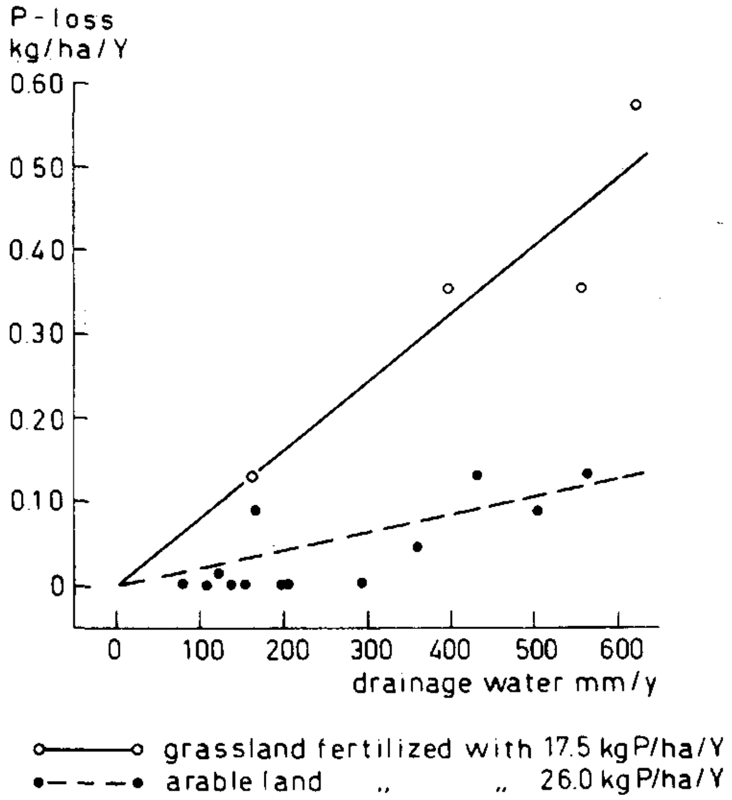

Fig. 3 Annual leaching of phosphorus from cropped lysimeters. (depth of profile approx. 1m).

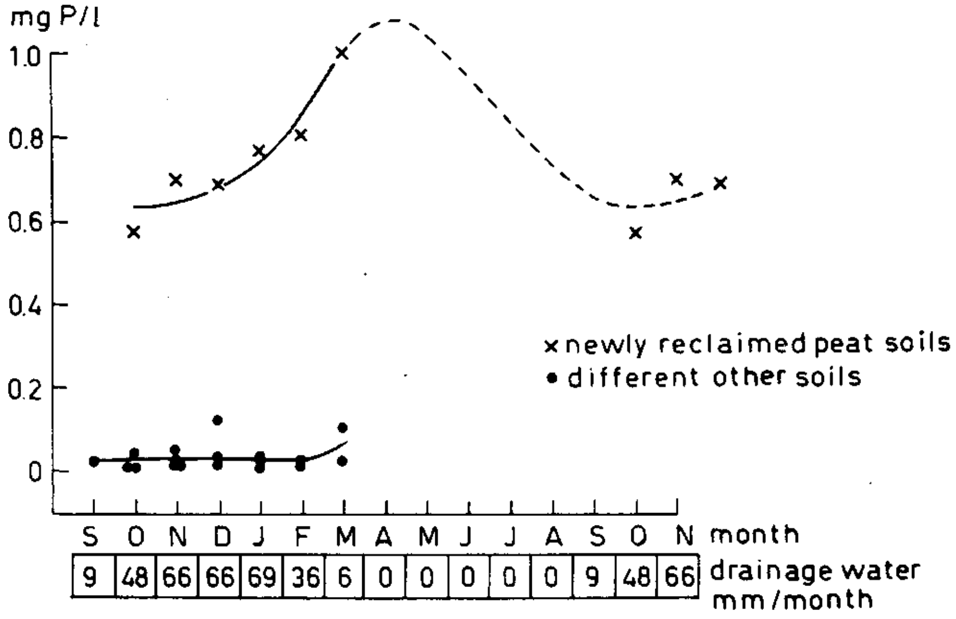

Fig.4 The total phosphorus content of drainagewater from different types of arable soil in the Netherlands (Henkens).

2. Run-off and erosion

A drawback of lysimeter studies is that erosion and run-off effects cannot be measured. But particularly by erosion large amounts of soil, containing nitrogen and phosphorus, can be discharged into the surface water. Relatively little information regarding the amount of nitrogen and phosphorus actually transported is available, however.

Cook (1969) has given an equation to predict soil losses by water erosion. This equation is:

$$A = R.\ K.\ L.\ S.\ C.\ P.$$

A = computed soil loss per unit area
R = rainfall factor
K = soil erodibility factor
L = length of the slope factor
S = steepness of slope factor
C = cropping and management factor
P = conservation factor

To calculate the loss of total nitrogen and phosphorus, the amount of soil (A) can be multiplied by the total nitrogen- and phosphorus content of the soil. As only a part of this nitrogen and phosphorus will dissolve we have to add also a "solubility" factor.

It is clear that this equation can be used for very small, well defined areas. But it is practically impossible to get results for large areas. Therefore, well established mean values for these regions are lacking.

However, the effects of water and wind erosion,(surface) run-off included, can be studied also by means of nutrient balance sheets for brooks and rivers. Such results can be compared with lysimeter data to obtain an impression of the effect of erosion. A drawback is now that direct pollution of the surface water with animal waste cannot be distinguished from erosion effects in such studies. Therefore, it is necessary to analyse the results from different regions with differences in run-off, erosion and direct pollution with animal waste.

From the above-mentioned equation it becomes clear that the effect of water erosion in the Netherlands where about 70% of the cultivated soil is flat grassland, will be very small. Some run-off can take place only on heavy clay soils with poor permeability, and in winter when the soil is frozen and thaw sets in. It is impossible, however, to give any quantitative data about the extent of this factor in the Netherlands.

3. Direct pollution with animal waste

In the previous paragraph we pointed out already that nutrient balance sheets for brooks and rivers can give us some information about the extent of direct pollution with animal waste but that a separation between effects of run-off and animal waste pollution is not simple. The fact that research in catchment areas has been very inadequate in the Netherlands does not make the problem any easier.
Another complication in this type of research is the effect of rural habitation on the pollution of surface waters. Before studying the pollution with animal waste we will first give some attention to the effect of rural habitation.

A. Effect of rural habitation

Man takes up about 13,0 g N and 1.50 g P daily in his food (verslag van de Landbouw 1966). These amounts are fully excreted in faeces and urine except a small amount that is resorbed in the human body, but this will be neglected. The total daily production in domestic sewage water according Imhoff (1950) is 12.8 g N and 1.75 g P per capita. Based on these figures we obtain the following annual production per capita.

TABLE 5. Nitrogen and phosphorus produced in human domestic sewage water in kg/year/capita excluding detergents

	N, kg	P, kg
faeces and urine	4.5	0.55
domestic waste water	0.2	0.10
total domestic sewage water	4.7	0.65

The contribution of detergents was so small in 1950 that this amount can be neglected. However, during the last 20 years there was a strong increase. Douma (1970) reported a rise in sodium polyphosphate consumption (25% P) from 400 tons in 1950 tot 40,000 tons in 1970. This whole amount is used in housekeeping. With a population of 13×10^6 people this is per capita:

$$\frac{40 \times 10^6 \times 0.25}{13 \times 10^6} = 0.77 \text{ kg P/year}$$

So the amount of phosphorus in domestic waste water in 1970 can be estimated per capita at 0.10 + 0.77 = 0.87 kg P/y. This means that 53% of the total phosphorus in domestic sewage water now originates from detergents. The current nitrogen and phosphorus production per capita is 4.7 kg N/y and 1.42 kg P/y.

As the mean density of the rural population living on our farms is about 0.5 persons/ha, it is evident that the amount of phosphorus discharged in domestic sewage water will be higher than the phosphorus loss found in the lysimeter experiments. Therefore, the density of the rural population discharging sewage water into water courses cannot be neglected in catchment area research. However, it is difficult to predict what and how much will flow into drains. In some cases only the large volume of domestic water is

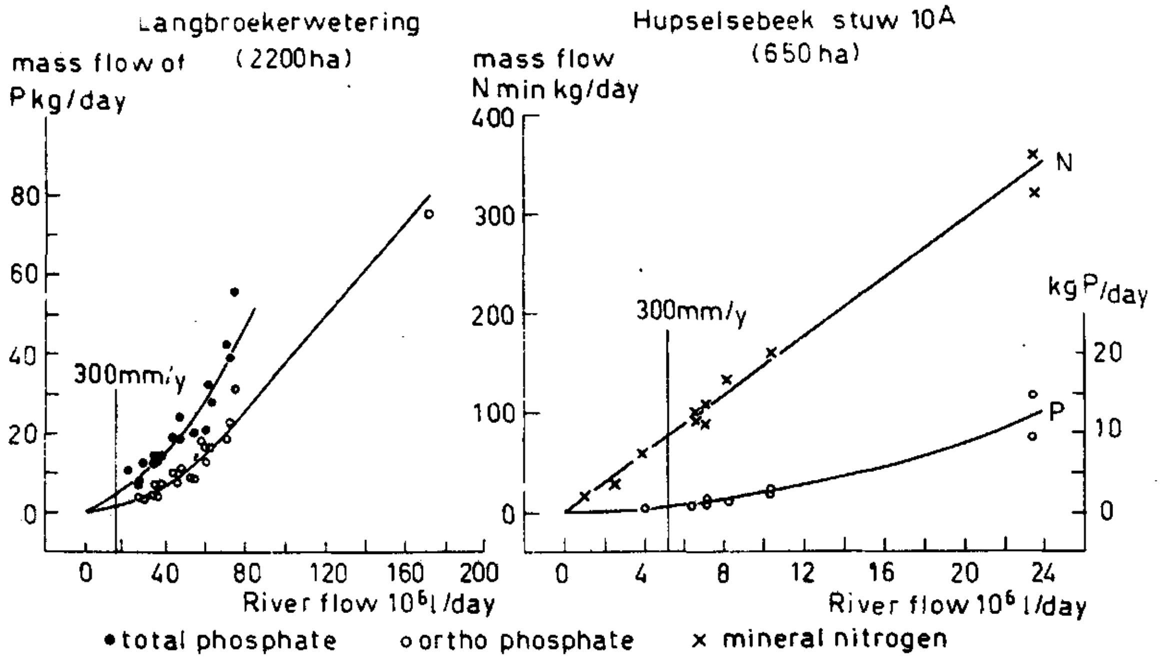

Fig. 5 Mass flow of mineral nitrogen and total phosphorus in two rivers in the Netherlands

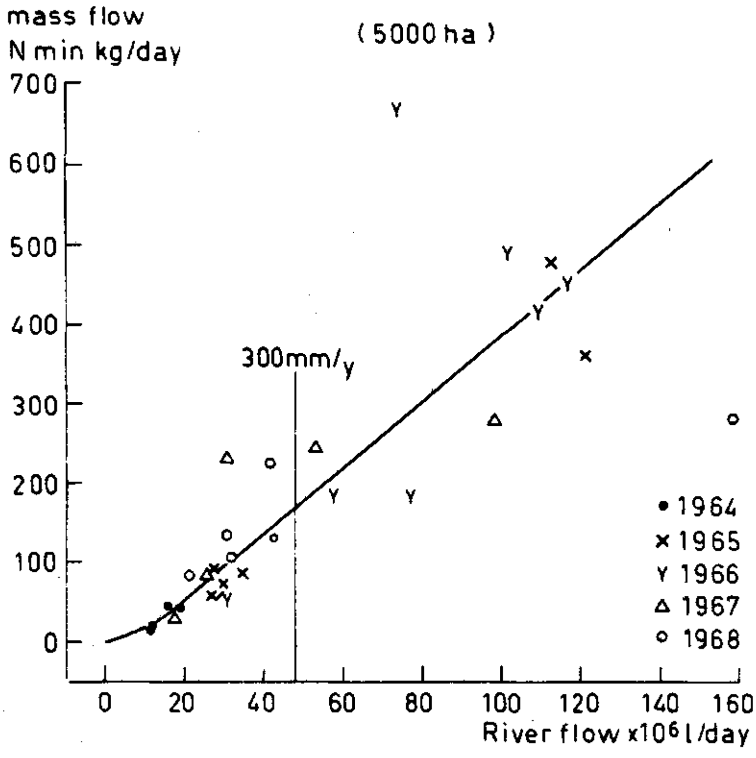

Fig. 6 Mass flow of mineral nitrogen from the Hierdense beek (rapport Homan)

discharged into ditches. In other cases faeces, urine and domestic waste water are caught in septic tanks. A part can be used as organic manure, but it is also possible that a greater part will be discharged directly. In dry periods the waste water can move downward in the soil and the phosphorus will be fixed there.

In the following paragraph we shall try to separate both effects viz. rural-living and animal waste.

B. Effect of animal waste

Some results from catchment area research are given in table 6. The results 1 to 4 are calculated from analysis of Golterman (1970) assuming that the mean total water flow under our climatic conditions is about 300 mm/y. The data from no. 5 are based on own experiments (see also fig. 5), those from no. 6 have been gathered by the Prov. Office of Public Works in Utrecht (see also fig. 5), whilst the data from experiment no. 7 have been taken from a report by Homans(1970), prepared for the Prov. Office of Public Works in Gelderland (see fig. 6). Finally, the results from Flevoland (no. 8) for nitrogen are taken from Van Schreven (1970) (see fig. 7) and for phosphorus from Golterman (1970).

By subtracting the amounts expected due to leaching based on lysimeter research (for grassland 13 kg N/ha and 0.24 kg P/ha)fromthe total losses we find the sum of the direct pollution from rural living and animal waste according the equation:

total loss = leaching loss + animal waste + population waste

From the relation P-loss and population density (fig. 8) we estimate that per capita about 0.2 kg P/ha/y or 14% of the total phosphorus is contributed to surface waters. On the basis of this percentage the correction for nitrogen would be 0.14 x 4.7 = 0.66 kg N/pers/ha/y.

We can now subtract this amount from the sum of population and animal waste, to find the effect of the latter only.

TABLE 6. The total nitrogen and phosphorus loss from some catchment areas and the contribution from animal waste and rural habitation in the Netherlands.

Catchment area	Population density pers/ha	% grassl.	Losses in kg/ha/year total		lysimeter		population and animal waste		animal waste		Nutrients produced in org. manure kg/ha/year		
			N	P	N	P	N	P	N	P	N	P	K
1. Oosterwolde	0.65	90	-	0.35	-	0.24	-	0.11	-	-0.02	80	15	75
2. Kamperveen	0.65	90	-	0.42	-	0.24	-	0.18	-	+0.05	80	15	75
3. Bijselsebeek	0.90	88	-	0.42	-	0.24	-	0.18	-	0	80	15	75
4. Puttenerbeek	0.90	88	-	0.64	-	0.24	-	0.40	-	0.22	-	-	-
5. Hupselsebeek	0.30	80	56	0.52	13	0.24	43	0.28	42.8	0.22	150	36	104
6. Langbroekerwet.	0.20	90	-	1.37	-	0.24	-	1.13	-	1.09	144	37	94
7. Hierdensebeek*	2.00	100	22	2.49	13	0.24	9	2.25	7.7	1.85	180	37	148
8. Flevopolder	0.05	5	24	0.16	24	0.06	0	0.10	0	0.09	0	0	0

* After correction for 50% forest on basis of 4 kg N/ha and 0.052 kg P/ha found by Minderman and Leeflang (1968) in an unfertilized dune sand lysimeter.

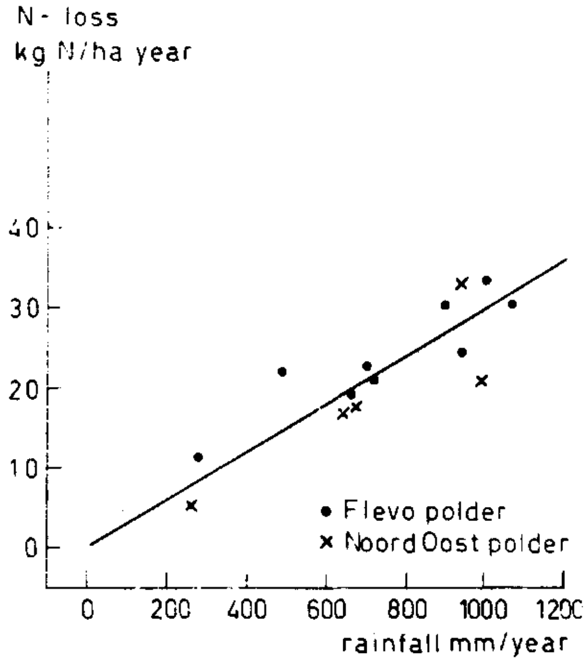

Fig. 7 Leaching of mineral nitrogen as a function of rainfall. (van Schreven 1970.)

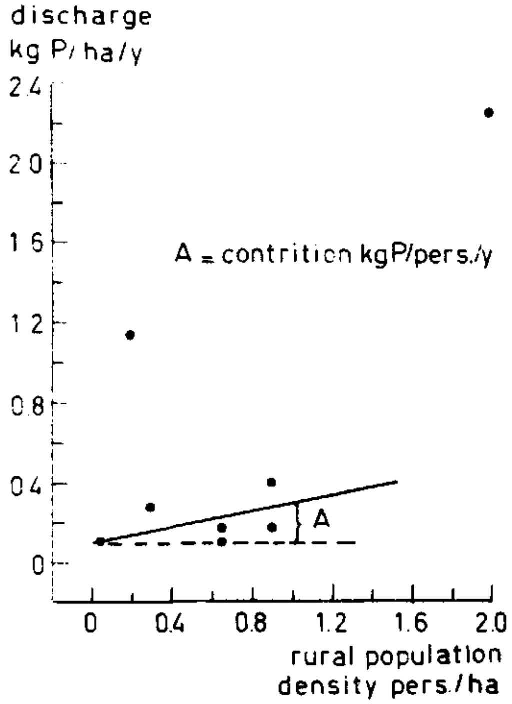

Fig. 8 Relation between rural population and P-discharge in surface water

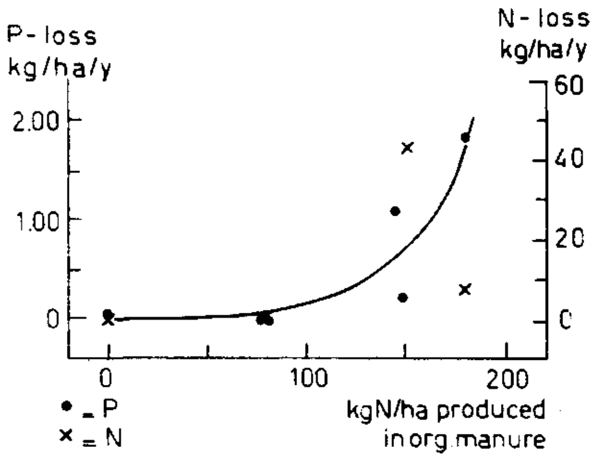

Fig 9 The relation between P and N-losses from animal waste and the total nitrogen production in organic manure.

From table 6 it is apparent that this effect ranges from -0.02 - +1.85 kg P/ha/y, which is a relatively small amount in relation to the total phosphorus production in the organic manure.

In the Hierdensebeek nearly 5%, in the Langbroekerwetering 3 % and in the area of the Hupselsebeek 0.6% of the total phosphorus production in the organic manure is lost in this way.

For the nitrogen we calculate a loss of 28% in the Hupselsebeek area (no. 5) and 4% for the Hierdensebeek (no. 7).

In Figure 9 we have plotted the calculated N- and P-losses due to animal waste against the total N-production in organic manure. Figure 9 shows that these losses are increasing strongly above a production of 100 kg N/ha (100 kg N/ha is equivalent to about 2½ cattle units/ha). The real reason is that the farmer has a large excess of potassium in his organic manure, which he does not like to apply to his grassland because of grass tetany hazards, when livestock rates exceed 2½ cattle units/ha.

As the mean production to-day is about 100 kg N/ha, we can estimate the annual contribution to eutrophication from animal waste at 0.2 kg P/ha and 5 kg N/ha. For an area of 2.1×10^6 ha cultivated land this is 0.44×10^6 kg P and 11×10^6 kg N.

The high ratio of N/P = 195 of the discharged animal waste products in the Hupselsebeek area is an indication that here urine is drained off. This liquid manure is rich in nitrogen (0.42% N) and low in phosphorus (0.009% P) and has a N/P ratio of 48. That the N/P ratio found is much higher may be caused by fixation of P in the sludge on the bottom of the brook.

As contrasted with this, the slurry from calves discharged in the Hierdensebeek area has an N/P ratio of 4.9, which is nearly the same as that calculated for the N and P losses in the surface water, viz. 7.7/1.85 = 4.2.

We have calculated the N and P losses as percentages of the total N and P produced. But when we assume that in the Hierdensebeek area only the slurry of calves is discharged this part can be calculated to be 9% of the P produced in the slurry(1,85/22 x 100) which is a relatively high rate.

4. Total contribution of agriculture

Now we can make an estimation of the total contribution of agriculture to eutrophication of surface waters.

A summary is given in table 7.

TABLE 7. The total annual contribution of agriculture to eutrophication of surface waters in the Netherlands.

	area, ha	N, kg	P, kg
arable land	775,000		
leaching		42×10^6	0.10×10^6
animal waste			
grassland	1,350,000		
leaching		17×10^6	0.32×10^6
animal waste		11×10^6	0.44×10^6
total	2,125,000	70×10^6	0.86×10^6
per ha/y		34	0.40

From table 7 it is evident that the total contribution is about 70 million kg N and 0.86 million kg P.
There is yet another source of direct pollution of surface waters in agriculture. This comes from mechanical application of fertilizer by centrifugal spreaders. Part of the fertilizer is spread into the ditches too. However, this part of the total direct pollution is included in the effect of animal waste and difficult to separate.

III. PAST, PRESENT AND FUTURE TRENDS IN FERTILIZER CONSUMPTION

There are three pathways in which plant nutrients reach the soil:

1e. in fertilizer
2e. in organic manure
3e. in rain water

The amount of plant nutrients in rain water are relatively small and will not be considered.

1. N and P in fertilizer

Figure 10 shows the fertilizer consumption in the Netherlands.

The amount of applied nitrogen per ha depends strongly on the type of crop. Therefore we have tried to make an estimation of the area of grassland and arable land up to the year 2000. In Figure 11 we see that the area of cultivated land is decreasing because every 5 years about 30,000 ha of agricultural land is taken out of production for different other purposes (Landbouwcijfers 1971, table 13b). In the period 1970-2000 this decrease can be estimated at about 180,000 ha. The amount of cultivated land will be about 2 million ha in the year 2000.

Figure 11 also demonstrates that the area of arable land has been decreasing strongly since 1960. This decrease takes place nearly entirely on sandy soils. The farmer prefers grassland to arable land from the financial and technical point of view. If we estimate that about 50% of the arable land will disappear in the next thirty years, we expect in 2000:

grassland	1,550,000 ha
arable land	350,000 "
horticulture	100,000 "
total	2,000,000 ha

In 1970 about 175 kg N/ha was used in the Netherlands. This means an annual application of 100 kg N/ha on arable

For an area of 2×10^6 ha cultivated land this is 175 kg N/ha/y, 39 kg P/ha/y and 145 kg K/ha/y. Assuming that of the total nitrogen 50% will be available to the plant, the total amounts of nitrogen, phosphorus and potassium available in 2000 will be:

	N	P	K
fertilizer	245 kg/ha/y	5 kg/ha/y	17 kg/ha/y
org. manure	87 "	39 "	145 "
total	332 kg/ha/y	44 kg/ha/y	162 kg/ha/y

We have estimated in Figure 11 that in 2000 the ratio of arable land to grassland will be about 1:4. Hence the grassland has to accept the greater part of the organic manure. The annual requirement for N, P and K on grassland is about 275 kg N/ha, 20 kg P/ha and 100 kg K/ha. Also when this need will increase somewhat due to higher dry-matter production, it is clear that the amounts of P and K in the organic manure are far too high for our grassland. This is especiallytrue for the amounts of potassium with a view to the grass tetany disease in grazing cows.

In fact the amounts of N, P and K applied in organic manure are even higher than calculated here as the distribution over the total area of cultivated land is not homogeneous.

Here we are facing the problem of the organic manure surplus. It will be a continuous danger to the quality of our surface waters.The farmer has found a partial solution of the problem by discharging a part of the urine containing N and K into the surface waters, resulting in an increased nitrogen content of this water. The phosphorus content,however, will be influenced to a much lesser extent, because urine contains little phosphorus. On the basis of Figure 9 we may expect that the mean contribution from animal waste will increase in the next 30 years for phosphorus from 0.2 to 1.6 kg P/ha/y, and for nitrogen from 5 to 40 kg N/ha/y. This constitutes an eight fold increase if no action is taken.

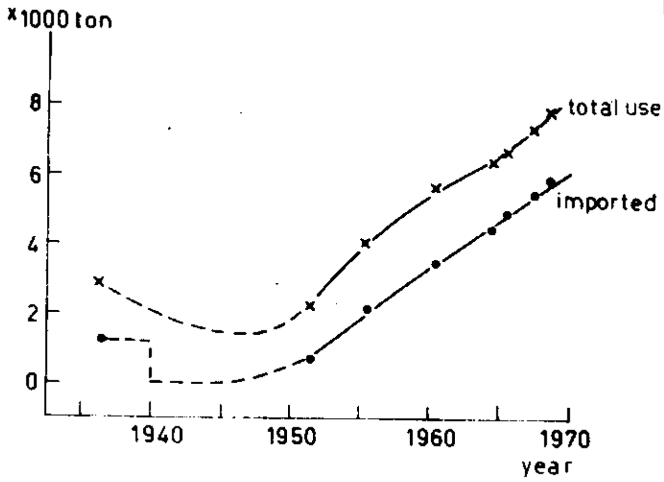

Fig. 12 Use of concentrated feed for cattle in the Netherlands.

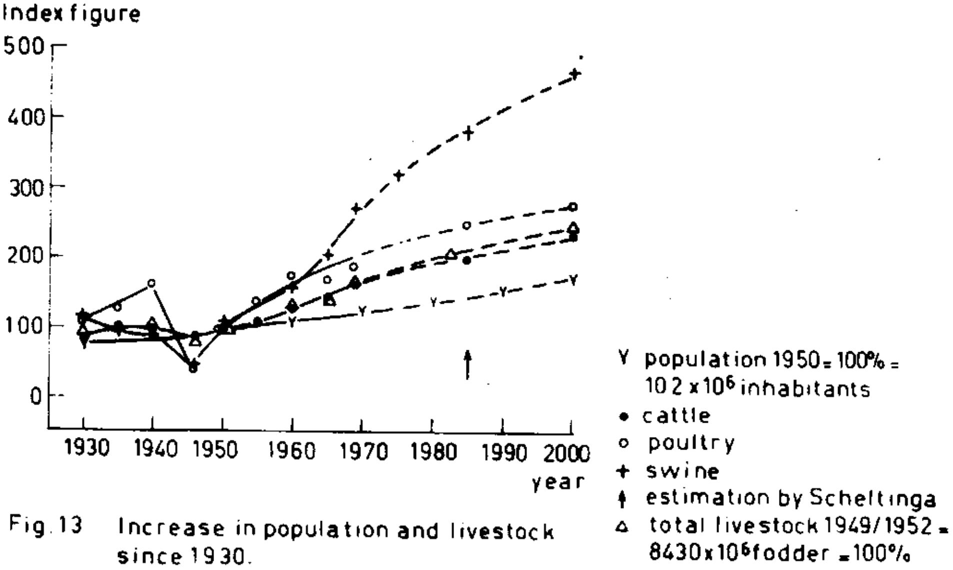

Fig. 13 Increase in population and livestock since 1930.

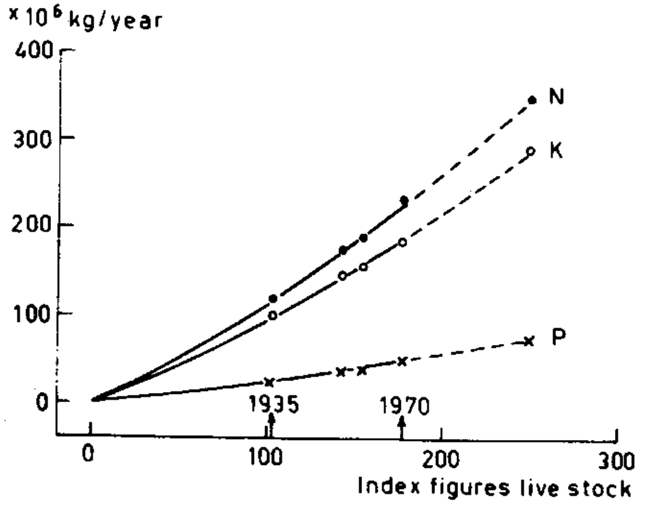

Fig. 14 Production of total nitrogen, phosphorus and potassium in organic and liquid manure in the Netherlands.

IV EVALUATION OF THE SIGNIFICANCE TO THE WATER SYSTEM OF AGRICULTURAL SOURCES OF NUTRIENTS

To evaluate the significance to the water system of agricultural sources of nutrients, we have to see them in relation to other sources of pollution. Therefore we can use nitrogen figures published by Revallier (1971) and phosphorus data of Beek (1971). The values for agriculture are those calculated in this report. Table 8 shows the result.

TABLE 8 The total nitrogen and phosphorus contribution to eutrophication from different sources in the Netherlands

Source		N		P	
		10^6 kg/y	%	10^6 kg/y	%
Rivers					
Meuse (Eysden)		24	4.7	3.0	5.0
Rhine (Lobith)		280	55.2	35.0	56.5
Rainfall*		17	3.4	1.75	2.7
Agriculture soil	36				
leguminous plants	4				
fertilizer	10			0.42	0.7
org. manure	9				
animal waste	11			0.44	0.7
sub. total	70	70	13,8	0,86	1.4
Population		54	10,7	18,0	29.0
Industry		62	12.2	3.50	5.5
Total load		507	100	62,11	100

* Only on 550,000 ha surface water

From table 8 it is clear that eutrophication in the Netherlands is primarily an international problem as 60% of the nitrogen and phosphorus originates in the river Rhine and Meuse.

On a national level we see that the direct contribution of rainfall to surface water pollution is about 3%. However, this part cannot be easily influenced. Perhaps it will be reduced to some extent as also air pollution will diminish.

The three remaining sources, agriculture, population and industry make about the same nitrogen contribution. However, the nitrogen form can be very different. The mineral nitrogen in domestic sewage is nearly completely ammonia, which demands oxygen from the surface water for oxidation to nitrate. This is also the case with animal waste, but 85% of the nitrogen discharged by agriculture (leaching) is in the nitrate form, which has no oxygen demand but supplies it under anaerobic conditions.

As regards phosphorus the high contribution from the population of 29% is striking, industry and agriculture only supplying 5.5% and 1.4% respectively. The part of agriculture in phosphorus pollution is small. However, we have seen that without any intervention the contribution of animal waste will increase 8 times in the next thirty years and will then have reached the same level as industry now.

An important factor is that pollution by population and industry are point discharges, whereas we find in agriculture mainly discharges of the diffuse type. From a technical point of view it is therefore preferable to treat the sewage water from population and industry. But from table 8 it is also evident that a drop in the phosphorus concentration of surface water can be achieved only if the phosphorus in domestic and industrial waste water is removed by chemical precipitation. Biological oxidation alone is of little value in this respect, because only 30% of the phosphorus is fixed in the sludge. This procedure used on an international level will cause also a drop in the phosphorus flow in the river Rhine and Meuse.

From table 8 it can be calculated that by stopping the use of fertilizer and organic manure, and without increasing green manuring, a drop of 3% in the total nitrogen-load could be achieved. But the consequence would be a decrease in the fertility of our soils. Besides, it would not solve our problem in the next decennia in view of the large stock of nitrogen and phosphorus in the organic matter of our soils.

V. LAW CONCERNING POLLUTION OF SURFACE WATER

A short description of the new law concerning the pollution of surface water in the Netherlands was published by the Ministry of Transport and Public Works (1971).

About 1930 purification of sewage water started in the Netherlands. Now (1971) about 5% of the sewage water or 1 million i. e. (= inhabitant equivalent) yearly is discharged directly into the sea (Koot 1969). From the remaining quantity (20 million i. e. /y) 35% or 7 million i. e. /y is purified in 437 municipal and 100 non-municipal installations. Thus 13 million i. e. /y are discharged into the surface water, which has a capacityfor self purification of about 4. 5 million i. e. /y. For 1986 the estimation is an increase in total sewage water production to 31 million i. e. /y (16. 5 million i. e. of domestic and 14. 5 million i. e. of industrial origin, excluding 19 million i. e. /y from the potato and strawboard industry in the province of Groningen).

The installations now being used for purification are of the biological type and not supplied with chemical equipment. The phosphate and nitrate removal in such installations is about 30% (Bayley 1970, Koot 1970), so only 0. 35 x 30% = 10% of the total phosphate and nitrate is removed. As 5% is drained directly to the sea, the surface water in the Netherlands is loaded with 85% of all phosphate and nitrogen originating from sewage water.

The new law interdicts every type of artificial pollution of surface water. That means that natural run-off and drainage water from agricultural land does not constitute pollution according to this law.

The law forces all water control agencies (government, provinces, municipalities and polder boards) to attack artificial pollution. The government is only responsible for governmental waters (rivers, canals, lakes and territorial sea waters), the provinces, municipalities and polder boards for the remaining surface water.

Loading of surface water with sewage will only be possible with the permission of the water control board in question. For such permission everybody has to pay in accordance with the type and extent of the source of pollution. For the present the government will use only the i. e. as the unit of pollution. The other water control institutions (provinces, municipalities, polder boards) may use other units, for instance amount or composition of the waste water, or a fixed amount per m^3 of living accomodation. Hence the citizen has to pay for disposal of his domestic sewage water, the industry for industrial waste water and the farmer for direct pollution of surface water with urine or slurry from his cattle.

With these taxes the water control board has the possibility to build installations for purification of sewage water. However, if for an industry the costs of purification grow out of all proportion, the water control board can pay a compensation. Also when a permit has to be refused, with the consequence of closing or moving, the industry can ask for compensation from the water control board in question. When these costs of compensation become too high, governmental support can be asked for.

In technical and chemical fields the water control boards have to co-operate with the governmental Institute for Purification of Sewage water (RIZA). The public health inspector, who inspects the water quality must be informed of every change in conditions on the basis of which a permit was issued.

VI. PRACTICAL CHANGES WHICH CAN BE ADOPTED TO REDUCE THE EFFECTS OF THE AGRICULTURAL CONTRIBUTIONS OF NUTRIENTS

In chapter IV we have recognized on a national level, the(still increasing) population as the principal cause of eutrophication with phosphorus. The contribution of agriculture was shown to be small, being only 4% of the combined contribution of population and industry (table 8). Even the direct contribution of rainfall to the surface water is higher! It became also clear that this P-loss in agriculture for the present can be reduced only to 50% by preventing direct pollution with animal waste. The other 50% cannot be diminished because the organic matter of the top-soil contains a high amount of phosphorus which is lost very slowly as a diffuse discharge. This part must be accepted as the basic contribution of agriculture to eutrophication with phosphorus.

The contribution of nitrogen from agriculture is of the same order as that from population and industry. But 85% of this discharge is of the diffuse type. That means that a direct water treatment as for domestic- or industrial sewage water is practically impossible owing to the large volume of water. Eutrophication with nitrogen as a result of leaching is associated with arable land, especially on light sandy soils. A direct reduction in leaching losses of nitrogen is possible to a limited extent by means of nitrification inhibitors. In practice this method is used on newly reclaimed peat soils which are treated once every 2-3 years with DD (dichloropropane-dichloropropene) against potato nematodes. However, it is an expensive tratement (ƒ 400, -/ha) and it is not known how soil fauna and flora will be affected by annual application. Hence we do not see many possibilities for this system of artificially preventing leaching losses.

It is also possible to change arable land into grassland. On the sandy soils already 70% of the cultivated land is grassland. The fact that the area of arable soil is still decreasing these soils, is a favourable factor. On clay soils this effect will be much smaller as table 4 shows. The total conversion on sandy soils from arable land to grassland would reduce the mean total loss per ha of cultivated land from 29 to 19 kg N/ha, or nearly 35%. We have seen that the contribution made by fertilizers is small, because only 3% of the amount applied was lost by leaching. The conversion of arable land to grassland will also here be a favourable factor. In spite of an increase in the N-application from 100 kg N/ha on arable land to 275 kg N/ha on grassland in the future, the N-loss by leaching will decrease strongly.

As we pointed out already, decreasing applications of fertilizers will have little effect on eutrophication, but result in higher food prices, because of a loss in fertility and lower yields. The N and P flow in domestic sewage water, however, will continue to increase with population growth and increased imports of food.

In the light of these possibilities it is clear that new fertilizers will never contribute much to lessening the problem of eutrophication. However, we have to be very careful with new types of fertilizers, because they could worsen the situation, especially in the long run.

The greatest problem in agriculture, however, will be to stop the increasing production of animal waste. We have seen that so far the mean contribution of agriculture has been small, but that we expect that without any intervention this contribution will increase 8 times in the next 30 years. However, in areas with a high livestock density the situation is already unfavourable. The farmer found a way out for his large excess of nutrients in organic and liquid manure by discharging them into the surface water, a method discovered long ago by local authorities and industry.

The new law concerning the pollution of surface water now forbids the farmer to drain off his nutrients without a licence. But also by charging a fee for a licence we have not reduced the problem of eutrophication because it is impossible for any authority to give all the surface water a biological and chemical treatment. Therefore, the solution has to be found on the farm of the licence holder.

The farmer has the possibility of applying all the farmyard manure,urine or slurry to his land during the whole year. He is now over-manuring his land, not using it in the normal agricultural sense but as a sewer. On sandy soils, slurries will result in pollution of the subsoil and an increase in nitrate and phosphorus content of the ground-water. On clay soils with a smaller water penetration capacity, the run-off to the surface water will increase. The law concerning pollution of surface water does not consider this run-off as an artificial pollution, but the effect on eutrophication will be nearly the same. Perhaps a new law on "Quality of ground-water", which is under consideration, may prevent this over-manuring, which is, in our opinion, not tolerable. The consequence will be that the agricultural excess of nutrients must be removed from the farm (De la Lande Cremer (1970).

Here are different possibilities.

(1) Nearly complete immobilisation. Nearly all nutrients can be immobilized by mixing the manure or slurry with (dry) town refuse in heaps with controlled tipping. Appropriate measures should reduce the production of drainage water to a minimum; this water should be treated biologically and chemically in a sewage treatment installation before it is drained into the surface water.

Here the limiting factor is the cost of transport.

(2) Treatment of manure and slurry in a biological oxidation system. Ten Have (1971) reported on different experiments performed with oxidation systems in the period 1967-1971. The system involves treatment of slurry in activated-sludge installations with low loads, to get a minimum sludge production (load 200-300 g BOD_5/m^3/day, OC/load = 2 and a sludge concentration of 10 g/l);

A drawback was that about 60% of the dry matter of the slurry of swine and hen/manure had a high resistance to microbial activity resulting in a large amount of residual sludge, which has to be removed from the farm too. For the organic matter in urine this was only 30%. With hen/manure the amount of surplus sludge was even higher than the original quantity of hen/manure used!

The remaining 40-70% organic matter requires a high amount of oxygen for oxidation. However, in spite of the high reduction percentages (95-97.5%) in BOD_5, the effluent still has a high amount of BOD_5 (0-200 mg/l), ammonia (0-750 mg N/l) and nitrite (0-300 mg N/l). During disturbance in the process these contents can sometimes be higher. The cause of these high contents in the effluents, is not quite clear, but it is evident that these effluents to some extent, still cause local pollution of the surface water. Hence treatment of the effluent during several days will be necessary.

However, from the point of view of eutrophication a low BOD_5, ammonia and nitrite content is not enough. The nitrogen and phosphorus in the effluent have to be removed also. This again will increase the cost of such an installation, which is already high for the individual farmer (about *ƒ* 25,- per inhabitant equivalent).

To prevent high costs of construction the installations are not fully automatic. So there will always be the danger that part of the waste will be drained off without sufficient purification by failing supervision and lack of knowledge of purification technology. An important advantage of this method is that the bad smell caused by application of untreated slurry of swine to the fields is completely eliminated after treatment in an oxidation installation.

(3) Separate treatment of solid and liquid manure. Voorburg (1971) comes to the conclusion that an activated sludge process has good prospects only in the case of urine, which has a low content of organic matter and phosphorus.

Such a treatment will be only possible when animal waste can be separated into a solid and liquid part (cattle, swine and calves).

The cost of purification in biological oxidation systems for liquid manure will be relatively low; such systems can be used by groups of farmers (co-operating with municipalities), because transport through pipelines is relatively easy. However, as opposed to slurry, the cost of cleaning stables mechanically is higher.

The farmer who has grassland and/or arable land can apply the solid manure to his land. Its storage is much easier and cheaper than of slurry, and the solid manure can be used at the best time, which will influence the leaching losses favourably. Because a great part of the excess nitrogen and potassium is removed with the liquid manure, the farmer can apply more solid manure, without the risk of over-manuring. Because the water content of this manure is much lower than of slurry, the penetration velocity of nitrogen and phosphorus into the subsoil will be less.

The farmer with little or no land can transport his excess of solid manure to an official town refuse dump.

If there is no possibility to transport the solid manure to an official refuse dump, it can be dried or burned after hydraulic pressing. The transport of ash from the farm will be no problem; however, burning will give air pollution.

To prevent increasing eutrophication due to animal waste in the future, it will be necessary to issue licenses for keeping high livestock rates e.g. more than $2\frac{1}{2}$ cattle units/ha, just as for settlement of an industry. The new law on pollution of surface water opens the possibility to control the development of this type of "bio-" industry and to demand various provisions. The extra costs made by the farmer can be paid by the water control board, because it will still be cheaper to prevent pollution than to clean up all the surface water after pollution.

This asks for intensification of research on the possibilities of immobilizing the excess of nutrients in organic manure to prevent pollution of the subsoil.

We have to realize that when we have eliminated all sources of pollution mentioned here, including the rivers Rhine and Meuse, there will still be one large source of nitrogen and phosphorus, in addition to the organic matter of our cultivated soils, in the form of mud and sludge on the bottom of our water courses. We will have no clear water without also cleaning up this bottom. But this is a problem for our water management authorities.

It is clear that "controlled eutrophication" has the consequence that agriculture has to learn thinking in three rather than two dimensions, so that in future people are able to buy meat instead of having to spend all their money on purification of surface water polluted with animal waste!

VII. CONCLUSIONS

1. 60% of the nitrogen and phosphorus load of our surface water originates from the rivers Rhine and Meuse, whereas 23% of the nitrogen and 35% of the phosphorus is contributed by population and industry.
2. The contribution of nitrogen and phosphorus made by agriculture to eutrophication is respectively 14% and 1.4% of the total N and P load.
3. 85% of the nitrogen, originating from agriculture, comes from leaching and is a discharge of the diffuse type, which does not lend itself to biological and chemical treatment.
4. The contribution of N-fertilizers to eutrophication depends on the type of soil and crop. On arable land the nitrogen leaching loss from fertilizers is about 10%, on grassland about 1% of the applied N-fertilizer. The mean contribution in the Netherlands to the total N-load of surface water is about 2%.
5. 50% of the total P-contribution of agriculture should be considered as a basic contribution to eutrophication, due to leaching losses from the large phosphorus store bound to the organic matter in the topsoil of our cultivated land. This part, however, is small and amounts to 0.06 kg P/ha/y on arable and 0.24 kg P/ha/y on grassland. The leaching loss is not appreciably influenced by the amount of phosphorus fertilizer applied annually. A reduction in these leaching losses is practically impossible to achieve.
6. In view of these small contributions one cannot expect new types of fertilizers to have an important effect on the reduction of nitrogen and phosphorus eutrophication.
7. A reduction in nitrogen leaching losses is possible by changing arable land into grassland. A tendency for this change to continue is expected. on the sandy soils for the next thirty years. This might result in a maximum decrease in the N-contribution of nearly 35% in spite of a strong increase in N-fertilizer use.

8. Today contribution from animal waste is of the same order as from fertilizers. However, an eight-fold increase may be expected in the next 30 years, as a result of an increase in livestock population of about 48%.
9. The new law concerning pollution of surface water opens the possibility of taking action to reduce this pollution.
10. A real reduction in eutrophication, however, will only be possible through biological and chemical treatment of all sewage water from population and industry because their contribution to the phosphorus load is as high as 35%.
11. For the Netherlands a reduction of more than 30% will be possible only if all the waste water from population and industry is treated in the entire catchment area of the Rhine and Meuse most of which is located outside its borders.

VIII. SUMMARY

An estimation was made of the N and P contribution of agriculture to eutrophication of surface water in the Netherlands. The losses through leaching were based on lysimeter results (table 4, fig. 3). Those of animal waste on catchment area research (table 6). An evaluation of this contribution was possible by making comparisons with other sources of nutrients as rainfall, rivers, population and industry (table 8). The total contributions of these different sources were:

	N %	P %
Rivers: Rhine and Meuse	60	60
Population and industry	23	35
Agriculture	14	1.4
Rainfall	3	3
Total	100	100

The most important conclusion is that the contribution of agriculture is relatively small. A real reduction in eutrophication by 25-30% will only be possible through biological and chemical treatment of all sewage water from population and industry. A stronger reduction is only possible by treatment of all the waste water in the catchment area of the rivers Rhine and Meuse, outside the Netherlands. The contribution of agriculture to N-leaching can be reduced by converting arable land to grassland. The maximum reduction in N-loss expected in this way in the next thirty years is nearly 35% of the total contribution of agriculture.

A very serious danger is the increasing pollution with animal waste. In the next 30 years an eight-fold increase is expected. However, a new law concerning the pollution of surface water opens the possibility of controlling this type of pollution more effectively. A result, however, will be, that part of the organic manure will have to be removed from the farm.Research on the possibilities of immobilizing or rendering harmless the excess of nutrients in organic manure, should be intensified.

IX. LITERATURE

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CONVERSION FACTORS

$N\text{-}NH_4(\%) \times 1.28 = NH_4(\%)$

$N\text{-}NO_3(\%) \times 4.43 = NO_3(\%)$

$P(\%) \times 2.29 = P_2O_5(\%)$

$P(\%) \times 3.06 = PO_4(\%)$

$K\% \times 1.20 = K_2O(\%)$

H.H. Titulaer

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