THE FERTILISER ASSOCIATION OF IRELAND

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FERTILISER USE SURVEY 1981 – 1982

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INTRODUCTION

Fertiliser Use Surveys have been carried out at intervals since 1964. The survey presented here, in common with most of the other Fertiliser Use Surveys, has been derived from the data collected by the personnel of the Economics and Rural Welfare Centre of An Foras Taluntais in the course of the Farm Management Survey. The fertiliser data collected from each farm is on a total crop rather than a field by field basis. It is therefore not possible to determine the area of a crop such as pasture that was not fertilised on a farm.

FERTILISER CONSUMPTION

Total nutrient consumption on a national basis is shown in Table 1. Nitrogen (N) use has increased almost every year whilst phosphorus (P) consumption reached a peak in 1972/73 and is now only 70% of that figure. Potassium (K) consumption is also below its peak level.

TABLE 1
Use of Lime and Fertilisers (1000't/year)

Year	*N*	*P*	*K*	*Lime*
1954/55	15	24	32	840
1962/63	30	49	74	1010
1967/68	53	64	102	1481
1972/73	130	90	154	1990
1977/78	230	76	171	2020
1978/79	264	80	184	1587
1979/80	248	68	157	959
1980/81	275	63	150	1348
1981/82	275	62	148	1592
1982/83	296	63	153	1886*

* *Estimate*

FERTILISER USE ON CROPS

Tables 2 and 3 show the levels of N P and K in kg/ha used on the main crops. The quantities for each crop are similar for the two years. Comment may therefore be confined to the results for one year — 1982. In the past N rates on cereals tended to be low. The situation is very different in this survey. The rates of N on feeding barley and wheat are greatly increased. Some of this increase is due to the move to Winter cereals and the tendency to have longer periods of tillage without a grass break. The use of N on root crops has also increased greatly except for sugar beet where it was always high.

The use of N began to increase on hay and silage in 1972 and on pasture in 1976. The use of P and K on the cereal and root crops has remained fairly satisfactory, but has declined on grassland to a position where the amounts of P and K applied are well below the amounts removed by medium-yield crops of hay and silage.

TABLE 2

Levels of N P K applied to Crops (kg/ha) 1981.

Crop	*N*	*P*	*K*
Wheat	174.0	47.9	103.1
Feeding Barley	102.9	34.4	71.1
Malting Barley	72.5	27.0	54.1
Oats	73.3	29.1	61.5
Potatoes	110.2	98.8	231.7
Sugar Beet	152.3	89.9	213.1
Fodder Beet	94.9	84.5	192.8
Swedes	63.6	72.1	130.4
Mangels	68.7	77.7	152.4
Hay	48.2	18.5	44.1
Silage	102.4	16.6	51.4
Pasture	48.4	8.4	17.4

TABLE 3

Levels of N P K Applied to Crops (kg/ha) 1982

Crop	*N*	*P*	*K*
Wheat	153.2	37.9	87.5
Feeding Barley	115.0	37.6	76.7
Malting Barley	75.5	27.4	54.9
Oats	63.7	30.7	61.4
Potatoes	117.1	102.6	245.4
Sugar Beet	157.8	93.0	224.4
Fodder Beet	97.5	76.0	174.4
Swedes	66.1	82.6	162.8
Mangels	68.9	66.3	141.0
Hay	45.9	17.6	42.0
Silage	104.9	15.9	50.7
Pasture	46.2	8.2	14.7

COMPARISON OF ESTIMATES

The amounts of N P and K used on crops in 1982 multiplied by the areas of crops (C.S.O. figures) are compared with the National consumption figures derived from Department of Agriculture records, averaged over 1981 and 1982. This comparison is shown in Table 4. The Fertiliser Use Survey figures give a slight overestimate. Some of this overestimate is probably due to the fact that very small farms are not included in the Farm Management Survey and they may have a lower than average fertiliser use especially on grassland.

TABLE 4

Estimates of N P K Consumption from Fertiliser Use Survey 1982 versus Department of Agriculture Records 1981–82

	Tonnes Nutrient		
	N	*P*	*K*
Department of Agr. Records	285586	62605	150583
Fertiliser Use Survey	298880	67470	156656
Bias (percent)	+ 4.7	+ 7.7	+ 4.0

FERTILISER USE IN IRELAND

The use of N P and K on pasture in each county for 1982 is shown in Table 5. These figures are not as reliable as the national average figures because of the lower number of records for each county. There are wide differences between counties for the three nutrients. In the case of N the range is from 4.2 kg N/ha in Leitrim to 101 kg N/ha in West Cork.

STOCKING RATE AND FARM SYSTEM

The relationship between stocking rate, farm system and the use of N on pasture is shown in Table 6. For each farm system there is an increase of N use on pasture with increased stocking rates. The very high usage of N at the high stocking rates are over-estimates because some of the fertiliser applied to the silage area for re-growth for grazing was attributed to the grazing area when the data was collected. Some of the very high stocking rates are also overestimated as no account is taken of the production of non-grass feed crops.

TABLE 5

Levels of N P K (kg/ha) Applied to Pasture on a County Basis 1982

County	*N*	*P*	*K*
Carlow	47.8	9.8	22.9
Dublin	28.3	7.6	15.2
Kildare	48.5	6.6	15.4
Kilkenny	64.0	11.7	25.3
Laois	36.7	7.9	15.8
Longford	31.2	6.6	12.5
Louth	74.3	11.6	23.9
Meath	43.7	5.2	11.9
Offaly	29.5	7.3	16.3
Westmeath	15.6	4.8	10.5
Wexford	94.6	9.7	19.8
Wicklow	42.5	11.1	22.6
Clare	22.2	7.5	13.9
Cork (E)	92.2	12.6	28.2
Cork (W)	101.6	15.8	34.3
Kerry	34.7	6.8	14.4
Limerick	47.4	6.3	12.0
Tipperary (N)	28.8	8.3	16.2
Tipperary (S)	69.9	10.1	22.4
Waterford	74.8	11.3	25.1
Galway	20.9	8.5	18.6
Leitrim	4.2	2.2	7.8
Mayo	18.5	7.1	24.0
Roscommon	14.4	9.0	17.6
Sligo	14.6	4.7	9.0
Cavan	43.2	7.2	14.4
Donegal	16.9	2.5	5.4
Monaghan	42.0	7.2	13.3

TABLE 6
Effect of Farm System* and Stocking Rate on N use (kg/ha) on Pasture 1982

Stocking Rate LU/ha	*1*	*2*	*3*	*4*	*5*	*6*
0.3	–	–	–	1.0	–	0.9
0.6	–	–	–	4.4	–	1.3
0.9	19.0	2.6	–	5.8	13.5	3.6
1.2	31.8	22.9	–	10.1	22.5	5.2
1.5	49.0	54.3	53.3	13.6	22.4	4.2
1.8	77.6	57.3	76.2	17.2	30.6	41.2
2.1	114.9	47.9	89.6	21.6	57.4	–
2.4	170.3	44.6	121.9	43.8	48.7	–
2.7	227.9	–	153.8	33.2	–	–
3.0	235.2	–	–	–	109.9	–
3.3	267.8	120.4	–	41.8	–	–

** Farm System*

1. *Mainly dairy*
2. *Dairy + dry stock*
3. *Dairy + dry stock + tillage*
4. *Mainly dry stock*
5. *Dry stock and tillage*
6. *Hill sheep and cattle*

The use of P and K also varied with stocking rate and farm system. The amounts of P used at medium stocking rates ranged from 6.2 to 12.9 kg P/ha between farm systems at 1.8 LU/ha whereas the N use ranged from 17.2 to 77.6 kg N/ha, i.e. four fold. The values are shown in Table 7.

TABLE 7
Effect of Farm System and Stocking Rate on P use (kg/ha) on Pasture 1982

Stocking Rate LU/ha	*1*	*2*	*3*	*4*	*5*	*6*
0.3	–	–	–	0.3	–	0.4
0.6	–	–	–	1.7	–	1.0
0.9	4.3	2.2	–	3.1	1.4	1.9
1.2	6.7	5.7	–	5.0	7.1	4.5
1.5	9.5	11.3	10.9	6.3	6.6	3.2
1.8	10.9	12.4	11.5	6.2	7.4	12.9
2.1	14.0	9.4	11.8	10.8	13.6	–
2.4	18.3	9.4	14.6	13.3	12.0	–
2.7	22.8	–	11.7	7.6	–	–
3.0	20.2	–	–	–	15.7	–
3.3	32.5	19.6	–	15.6	–	–

The use of K on pasture had a pattern similar to that of P. The use of N on hay and silage was not greatly influenced by stocking rate or farm system. This is illustrated in Table 8.

TABLE 8
Effect of Farm System and Stocking Rate on N use (kg/ha) on Silage 1982

Stocking Rate LU/ha	*1*	*2*	*3*	*4*	*5*	*6*
0.3	–	–	–	–	–	–
0.6	–	–	–	–	–	–
0.9	64.9	–	–	62.9	–	33.8
1.2	90.1	89.5	–	67.3	–	–
1.5	101.8	92.9	100.0	88.2	90.7	–
1.8	104.6	104.7	104.4	97.7	110.9	–
2.1	123.7	100.4	107.1	85.1	106.3	–
2.4	115.4	85.4	121.7	105.2	123.4	–
2.7	114.8	–	154.4	–	–	–
3.0	124.1	–	–	–	–	–
3.3	–	–	–	–	–	–

The silage and hay crops are treated as crops independently of the numbers of livestock. The supply of Winter feed is controlled by the areas used for hay and silage rather than by the fertiliser. The use of K for silage is on average low and there is no great variation between stocking rates or farm systems. The range of use varied from 20 kg K/ha for hill sheep and cattle to a maximum of 67.8 kg K/ha for silage on dairy farms at a stock rate of 1.8 LU/ha. This maximum is lower than the amount of K necessary to replace K removed in the crop unless large quantities of slurry are used.

COMPOUNDS

The sources from which the nutrients applied to each crop are derived are shown in Tables 9, 10 and 11. The use of 'straight' fertilisers as sources of P and K is very low whereas there is a tendency to increase the use of 'N only' fertilisers on cereals.

TABLE 9
Percentage of Total Nitrogen used on Crops 1982

Compound	*Wheat*	*Feeding Barley*	*Malting Barley*	*Oats*	*Potatoes*	*Sugar Beet*	*Feed Roots*	*Hay*	*Silage*	*Pasture*
6:10:18	–	–	–	–	–	1.1	46.3	–	–	–
7:6:17	–	–	0.3	–	37.2	–	0.9	–	–	–
9:6:15	–	–	–	–	0.5	78.2	10.9	–	–	–
10:10:20	1.3	13.1	10.3	19.8	43.9	0.5	4.9	11.9	1.2	3.5
14:7:14	1.1	8.4	28.0	5.4	7.0	–	0.3	2.1	0.5	0.9
18:6:12	3.2	21.7	30.9	24.8	1.9	1.2	6.1	22.2	4.4	7.7
24:2.5:10	–	–	–	–	0.3	–	–	6.3	14.5	7.4
27:2.5:5	–	0.3	–	–	0.4	–	–	8.3	8.6	15.0
27:5:0:0	79.9	50.5	30.5	39.8	1.0	16.8	6.6	33.4	40.8	41.3
46:0:0	11.1	3.7	–	8.5	–	0.5	–	9.5	25.0	18.1
Others	3.4	2.3	0.0	1.7	7.8	1.7	24.0	6.3	5.0	6.1

TABLE 10

Percentage of Total Phosphorus used on Crops 1982

Compound	*Wheat*	*Feeding Barley*	*Malting Barley*	*Oats*	*Potatoes*	*Sugar Beet*	*Feed Roots*	*Hay*	*Silage*	*Pasture*
0:7:30	13.3	1.7	—	0.2	—	1.9	—	16.5	43.9	18.7
0:10:20	75.0	22.2	4.0	32.3	—	—	0.3	15.6	14.3	24.3
6:10:18	—	0.1	—	—	—	3.1	69.0	—	—	—
7:6:17	—	—	0.6	0.1	36.4	—	0.4	—	—	—
8:8:16	—	0.3	—	3.2	6.0	—	2.7	5.2	—	2.3
9:6:15	—	—	—	—	0.4	88.4	6.5	—	—	—
10:10:20	5.2	39.9	28.4	40.2	50.1	0.8	3.9	31.2	8.0	18.6
14:7:14	2.2	12.8	38.5	5.6	4.1	—	—	2.7	1.8	2.4
18:6:12	4.3	22.1	28.5	17.2	0.7	0.7	1.8	19.3	9.7	14.0
24:2.5:10	—	—	—	—	—	—	—	2.0	11.2	4.7
27:2.5:5	—	—	—	—	—	—	—	2.1	5.4	7.8
Others	0.0	0.9	0.0	1.2	2.3	4.9	15.4	5.4	5.7	7.2

TABLE 11

Percentage of Total Potassium used on Crops 1982

Compound	*Wheat*	*Feeding Barley*	*Malting Barley*	*Oats*	*Potatoes*	*Sugar Beet*	*Feed Roots*	*Hay*	*Silage*	*Pasture*
0:7:30	24.8	3.5	4.0	0.4	0.6	3.3		29.6	58.7	32.6
0:10:20	65.1	21.8	—	32.3	1.0	0.3	0.3	13.1	8.9	19.8
6:10:18	—	—	—	—	—	1.9	56.9	—	—	—
7:6:17	—	—	0.8	—	43.1	—	1.1	—	—	—
8:8:16	—	—	—	—	6.1	—	3.4	4.3	—	1.9
9:6:15	—	—	—	—	0.4	91.6	8.0	—	—	—
10:10:20	4.5	39.2	28.3	41.0	41.9	0.6	4.3	26.1	5.0	15.2
14:7:14	1.9	12.5	38.5	5.6	3.5	—	—	2.3	1.1	1.9
18:6:12	3.7	21.7	28.4	17.2	0.6	0.5	1.8	16.2	6.1	11.4
24:2.5:10	—	—	—	—	—	—	—	2.8	11.9	6.0
27:2.5:5	—	—	—	—	—	—	—	1.7	3.4	6.3
Others	0.0	1.3	0.0	3.5	2.8	1.8	24.2	3.9	4.9	4.3

POLLUTION ASPECTS OF FARM WASTES

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INTRODUCTION

The Water Pollution (1977) Act states that "a person shall not cause or permit any polluting material to enter waters". Those who wish to discharge polluting material directly to lake, stream or river are obliged by law to obtain a licence from a Local Authority. This applies equally to trade effluents from industry and to effluents from agricultural activities. Up to now, farmers have not applied for licences under this Act and Local Authorities have not pressed the issue because the Department of the Environment has not yet established standards for permissible discharge. Within a few years, when the Law is fully implemented, farmers will need to take stringent measures to ensure maximum purification of farm wastes before they reach a watercourse.

ORGANIC POLLUTION OF SURFACE WATER

Agricultural wastes cause water pollution primarily because they contain a high level of biodegradable organic matter. When the pollutant reaches water, bacteria consume the organic matter and multiply rapidly. The high population of bacteria use the dissolved oxygen in the water and fish die of asphyxiation because of the depleted oxygen status of the water.

Every organic pollutant requires a specific amount of oxygen for its biodegradation. This is described as its Biochemical Oxygen Demand (BOD value) and is expressed as milligrams oxygen used for the decomposition of the organic matter in one litre of the polluted liquid. Materials with high organic matter content have a high BOD value.

River water is classified as follows:

BOD value (mg O_2/l)	*Classification*
0 – 4	Clean
5 – 8	Poor quality
9 – 15	Bad quality
>15	Grossly polluted

Coarse fish might survive in poor quality water but fish could not live in bad quality water.

When the BOD values of farm wastes are viewed in this perspective their pollution potential becomes apparent (see Table 1).

TABLE 1

BOD Values of Farm Related Pollutants

Pollutant	*BOD value (mg O_2/l)*
Silage effluent	65,000
Pig slurry	25,000
Cattle slurry	17,000
Dirty water/Dairy washings	1,500
Milk	100,000
Untreated domestic sewage	400

The calculated total BOD load generated by the national animal herd and silage effluent is approximately 1.6 x 10^6 tonnes/annum, as detailed in Table 2. This is equivalent to the load which would be produced by a population of ca 80m people. Yet, the estimated BOD load which reaches waterways from agricultural sources is 10,091 tonnes/annum, which is considerably less than that which is currently discharged from domestic sewage 35,792 tonnes/annum by our 3.4 million people (Water Pollution Advisory Council Report, 1983).

TABLE 2

Total national animal numbers and estimated BOD loads

Animal	*Numbers (1982)*	*Estimated BOD Load (tonnes/year)*
Cattle	6,771,100	1,287,626
Pigs	1,141,100	41,650
Sheep	3,656,500	90,754
Poultry	10,000,000	18,250
Silage	14 x 10^6 tonnes	182,000
	Total	1,620,280
People	3,483,000	68,650

However, these favourable statistics do not mean that farmers can be complacent. The Central Fisheries Board allege that the majority of fish kills in this country are caused by silage effluent and that many polluted stretches of river are due to the ingress of various agricultural wastes. The main sources of agricultural pollution are:

1. Silage effluent
2. Animal manures
3. Dirty water
4. Run-off from land following spreading of slurry.

SILAGE EFFLUENT

Silage production has increased dramatically in the past 12 years from less than 4 x 10^6 tonnes in 1970 to almost 14 x 10^6 tonnes in 1982 (Boyle & Kearney, 1983). The amount of effluent produced varies according to the dry matter content of the grass ensiled.

Dry matter content of ensiled grass (%)	*Volume of effluent produced (l/tonne)*
15	220
20	160
25	50

Besides having a very high BOD value (Table 1) silage effluent also has the disadvantage that it reaches watercourses in summertime, when the volume of waterflow is low, temperature is high and the oxygen content of the water is already low. It is estimated that 1 litre of silage effluent can pollute more than 10,000 litres of water in these circumstances.

Patterson (1981) and his colleagues at Hillsborough have shown that silage effluent, properly preserved, is a suitable energy source for fattening pigs. It is unlikely, however, that many farmers will find this a practicable method for effluent disposal and for them, collection in a purpose-built tank and spreading on land, diluted 1:1 with water will continue to be the safest method of disposal.

ANIMAL MANURES

Most farmers make a conscientious effort to collect animal manures. Unfortunately the same effort is not always devoted to safe storage and disposal. The most common methods of collection of manure are:

(a) Under slatted floors
(b) Dungstead
(c) Farmyard manure

Under slatted floors: Collection under slatted floors, followed by spreading on land is generally a safe management system from an environmental viewpoint. However, since only 53% of the national drystock herd is housed over the winter and less than 2% of the total cattle are housed in slatted floor housing (Flynn and Feighery, 1977) only a fraction of the total cattle slurry is handled in this fashion. Most of the pig slurry is collected under slats and pollution from pig farms arises because of insufficient storage capacity at times when weather conditions do not permit spreading machinery to travel on land. Overflow of tanks or dumping through crude irrigation systems at these times can result in pollution of nearby waterways.

Dungstead: Storage in a dungstead-type structure is the most common system for dairy and beef farmers. Many of these structures are designed to let as much of the liquid as possible seep from the storage area. Improper collection and storage of seeping effluent is a serious pollution hazard on many farms. This effluent can have a BOD value of 5,000 – 15,000 depending on the amount of water which is mixed with the slurry. It should be collected in a special tank from which it should be spread on land by tanker at regular intervals. In practice the emptying of these tanks is frequently neglected and overflowing effluent may find its way to the nearest waterway, causing pollution. Alternatively, it may pond in shallow ground with a risk that it will leach to ground-water on shallow or sandy soil or through underlying fissured rocks.

Although handling slurry is unpleasant, it has an appreciable cash value as a fertiliser substitute and full advantage should be taken of its phosphorus and potassium content for silage production (Tunney, 1977). Under present spreading systems, most of the nitrogen in slurry is lost through volatilisation of ammonia and it is a challenge to research workers to improve the recovery of this nitrogen by either altering the design of the machinery for spreading or by treating the slurry with chemicals.

Farmyard manure: The collection of animal manures in houses where animals are bedded on straw may be regarded as an old-fashioned system but it poses very few environmental problems. The straw retains the offensive organic components and much of the carbon is dissipated from the manure heap by bacterial action during the composting process, which takes place naturally.

DIRTY WATER

The farm waste which poses the greatest problem to the dairy farmer is dirty water. This comprises yard washings following milking and run-off from concrete areas, and is produced at an approximate rate of 22 litres per cow place per day. This material has a BOD value of 1,500 but compared with slurry, it has a very low nutrient value, which makes its disposal an uneconomical proposition. Ideally it should be collected and irrigated onto land but pumps and pipes frequently get clogged with solids, and the system breaks down. Many farmers resort to storage in a blind ditch prior to discharging into a waterway. This system greatly reduces the BOD value, and the effluent may not damage the receiving water provided it is a fast-flowing stream containing a sizeable volume of water. If, however, the receiving water is a slow moving stream, the effluent will lead to an unsightly growth of sewage fungus, unpleasant smell and the ultimate destruction of its fish life.

SURFACE RUN-OFF

Landspreading is the safest method for disposal of slurry. It also ensures efficient recycling of nutrients. There is a danger, however, that if a heavy rainstorm occurs soon after spreading, a substantial amount of N, P, K and organic matter will be lost in surface run-off from heavy soils.

Research at Johnstown Castle has shown that the most important factor governing run-off is the time interval which elapses between slurry spreading and the occurrence of the storm which cuases run-off (Sherwood and Fanning, 1981). The data presented in Table 3 have been compiled from research results obtained at three different sites following landspreading in October 1980.

The results show that the BOD concentration in the run-off water dropped dramatically within the first week. In practice this means that there is very little danger of organic pollution unless a run-off storm occurs within 48 hours, when 20–30% of the total N, P, K and BOD applied can be washed off poorly drained land which is subject to run-off. This danger also applies to commercial fertilisers, and farmers would be well advised to check weather forecasts before spreading slurry or feriliser to eliminate this hazard.

TABLE 3

Composition of run-off water from storms which occurred at different time intervals following spreading of pig slurry at 3.6 t DM/ha

Time interval between spreading and run-off storm (days)	*Concentration in surface run-off water (mg/l)*			
	N	*P*	*K*	*BOD*
1	300	39	168	2,400
7	41	21	52	100
14	10	11	16	50
21	8	7	12.5	6
Amounts applied (kg/ha)	268	70	131	1,311

The results in Table 3 also show that the phosphorus concentration in run-off water at 21 days was high, relative to the other components. This concentration would not represent a significant nutrient loss but would be unacceptably high if the run-off water reached inland lakes.

Phosphorus is considered to be the nutrient which limits the growth of algae in lakes and the threshold orthophosphate — P concentration for the growth of algae is 0.01 mg/l (Vollenveider, 1971). The algal "bloom" has a short lifespan and when the algae die, the dead cells contribute organic matter for the multiplication of bacteria, which use up the available oxygen in the water, resulting in a fish kill. Where the run-off water reaches a fast flowing river in a maritime catchment such a high level of phosphorus would be unlikely to cause problems.

Other factors which affect run-off are rate of slurry application, soil type, slope and height of watertable.

INORGANIC POLLUTION OF SURFACE WATER

Ammonia Toxicity: Besides high organic matter, slurry and dairy washings also contain high levels of ammonia which can be toxic to fish if present in water in concentrations exceeding 2.5 ppm.

Herbicides and Pesticides: Careless handling of pesticides and herbicides and, in particular, dumping containers in and near waterways can result in fish kills from chemical toxicity.

SOIL POLLUTION

Dumping excess slurry and other farm wastes on land at rates which are greatly in excess of recommended rates, will ultimately destroy the nutrient balance of the soil, which may in turn lead to plant and animal disorders.

AIR POLLUTION

Odour: Of all the nuisances related to animal manures, bad odour is probably the one which evokes the most emotive reaction. Farmers would be wise to recognise this fact and should try to agitate and spread slurry in a manner which is least offensive to the general public.

Toxic Gases: Anaerobic storage leads to an accumulation of gases which at low concentration may lead to poor animal performance and at high concentrations may kill both humans and animals. Methane, ammonia, carbon dioxide and hydrogen sulphide are the most important gases and the latter is the most deadly. Hydrogen sulphide can cause instant mortality if present in the atmosphere in concentrations exceeding 1,000 ppm. These gases are released from slurry during agitation and consequently great care should be taken to provide maximum ventilation and to evacuate both people and animals from the immediate area when agitating slurry.

CONCLUSIONS

Agriculture is estimated to contribute 11.5% of the total BOD load which reaches waterways annually. This compares very favourably with the pollution load contributed from industrial and domestic sources.However, the main purpose of the Water Pollution (1977) Act is to ensure that the ***total*** BOD load is reduced and since much of the pollution currently contributed by agricultural wastes is through careless management, the full implementation of the law within the next few years will mean that farmers will be forced to improve their husbandry. This can best be assured by a comprehensive education programme. Only then will farmers fully appreciate the pollution potential of the materials they handle and play their proper role in preserving one of our most valuable national assets — our clean waters.

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AN ASSESSMENT OF THE IMPACT OF CURRENT FERTILISER USE ON WATER QUALITY IN IRELAND

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INTRODUCTION

Among the nutrients that are essential for plant growth and which are applied to land as fertilisers, nitrogen (N) and phosphorus (P) are the most important in the context of water quality. Appearance of either nutrient (but especially P) in surface water bodies may result in the development of excessive algal growth, leading in the extreme situation to total loss of amenity value. Enhanced N levels (as nitrate) are of particular concern from a public health standpoint.

Excessive nutrient inputs leading to various states of pollution in a number of Irish lakes was reported in 1975 (Anon, 1975; Flanagan and Toner, 1975). Part, at least, of this problem was attributed to agricultural practices (Anon, 1975). In general, there has not been a dramatic improvement in the overall condition of the affected lakes in the interim period. Between 1971 and 1979, the proportion of channel length in 121 major rivers that was classified as 'satisfactory' decreased from 83% to 72%: the length of river that was categorized as 'moderately polluted' increased by 12% (McCumiskey, 1980). Changes in the quality of the 31 rivers that were unsatisfactory in 1971 have been reported by Lennox and Toner (1980) for the period 1972—73 to 1976—78. Except for increases in nitrate-nitrogen content, there was little evidence of a deterioration in a number of other quality parameters. Enhanced nitrate-nitrogen content in these rivers was specifically associated with increased use of N fertilisers (Lennox and Toner, 1980; Toner and Lennon, 1980). Although McCumiskey (1980) has assessed the general quality status of Irish inland waters as 'predominantly satisfactory', the trend towards poorer river quality as well as the current unsatisfactory condition of some rivers and lakes was noted.

The general contribution of any sector (agriculture, industry, urbanisation) to a deterioration in water quality is a matter of considerable importance from a management aspect. In regard to nutrient contributions specifically arising from fertiliser use, concern should be all the greater because fertilisers are a relatively high-cost input into farming, the loss of which to water represents inefficient use by the crop. The present paper assesses in a general way the risk of nutrient leaching from fertiliser use in Ireland. The base year chosen for this assessment is 1980, since the most current land-use statistics refer to this year (Anon, 1983) and survey data for fertiliser use were available for 1979 (Murphy, 1983). It is concluded, for these conditions of total and pattern of use, that fertilisers are not a significant component of total nutrient loading to surface water bodies.

REACTIONS OF PHOSPHORUS AND NITROGEN FERTILISERS IN SOILS

Whether or not N and P appear in water following fertilisation depends primarily on (a) the efficiency of uptake of the nutrients by the growing crop following initial dissolution of the fertiliser in the soil water and (b) the extent to which the unabsorbednutrients remain in the upper (0—0.75m) portion of the soil during, or on completion of, the uptake process. Especially with N, these events are inter-dependent and there is no reason to suppose that under all conditions, one takes precedence over the other.

In mineral soils, most forms of P fertiliser dissolve rather quickly in the soil water but are then immediately adsorbed onto the surfaces of the clay-sized particles in an almost non-exchangeable form. This mechanism of P immobilization is rapid, is not affected by soil pH and is by far the most significant aspect of the 'P fixation' problem. Fixation of P by adsorption on to clay is supplemented by the occurrence of precipitation reactions which are affected by soil pH but which are quantitatively less important than adsorption. In highly sandy soils or in organic (peaty) soils, in both of which clay content may be low or very low, P fixation will be correspondingly low and hence the residence time for P in solution correspondingly high. Overall though, it may be concluded that the mobility of P in the average mineral soil is extremely restricted.

The water soluble forms of N fertilisers are ammonium, urea and nitrate. In practice, both ammonium and urea are converted in the soil to nitrate. Unlike P, N as nitrate does not react in any significant way with the clay fraction and consequently remains in the soil water in a highly mobile form. Under certain circumstances, some nitrate-nitrogen may be lost to the atmosphere through formation of nitrogen oxides and nitrogen gas, while a fraction of ammonium nitrogen or urea-nitrogen may also be lost from the soil by formation of ammonia gas.

Aside from nitrate derived from fertilisers, mineral soils contain variable amounts of organic N (including crop residues). Although the rate is not predictable, soil organic matter undergoes microbial decomposition to nitrate which mixes with nitrate that is already in the soil. Thus, at any time, the total pool of nitrate in the soil water is a composite of nitrate derived from fertilisers, nitrate derived from soil organic matter breakdown and, indeed, nitrate derived from some 'other' sources. Central to the problem of describing/understanding nitrate behaviour in soils is the fact that it is virtually impossible to apportion the nitrate in any location (crops, soil water, surface water or ground water) to that arising from a fertiliser application, that arising from soil organic matter or that which could arise from any other source (e.g. sewage, animal manures etc.). Irrespective of origin though, nitrate, in contrast to P, is highly mobile in all soils.

The foregoing then, suggests that the relative quantities of nitrate-nitrogen and P that are present in soil water or in drainage water should be very different. This is reflected in drainage water analysis from farms at Rothamsted Experimental Station that had been fertilised over the years, and also in soil water analysis carried out in University College Dublin (Table 1). Comparable data to these are available from a variety of research sources.

TABLE 1

Mean concentrations of nitrate-nitrogen (ppm N) and phosphorus (ppm P) in soil solutions (A) and drainage waters (B) from selected sites

		1	*2*	*3*	*4*
A[1]	N	4.7	18.6	6.6	1.3
	P	ND	0.49	0.57	0.67
B[2]	N	11.7	22.2	20.0	9.8
	P	0.02	0.14	0.06	0.51

1 Tan (1982); 2 Cooke (1976); ND = not detectable

LIKELIHOOD OF PHOSPHORUS LEACHING

Exceptional cases of leaching or run-off of P fertilisers may occur. This is evident from results obtained by Kiely and Roche (1981) on poorly permeable mineral soils and by Burke (1975) on sparsely vegetated blanket peat. Relatively large P leaching may also occur from sandy soils of low clay content (Cooke and Williams, 1970). All of these situations, however, are quite unrepresentative of the average farming situation and really cannot be used as evidence to support an argument for P leaching.

In essence, the P fixation capacity of the average mineral soil is unlimited and will not be sturated even with excessive rates of P fertiilisation. Accordingly, the concentrations of P in the soil solution or in the water that drains from land are not likely to be greatly influenced by the rate of P fertilisation (Cooke, 1976). Therefore, such regional differences in total P fertiliser use, or in rate of P use, as may occur in Ireland are essentially irrelevant in the context of P additions to ground or surface water.

Nevertheless, detection of P in drainage water does, in fact, mean that some loss to water can occur. An estimate of the magnitude of total loss that might occur can be made by applying the national mean value (700 mm) for total drainage McCumiskey, 1980) to the mean values for P concentration in drainage shown in Table 1. Where the maximum mean concentration (0.51 ppm) is taken, mean annual loss amounts to 3.6 kg/ha: on the other hand, when the minimum value (0.02 ppm) is assumed, the corresponding loss to water is only 0.14 kg/ha. Given the substantial dilution which drainage water undergoes on entry to receiving waters, it may be concluded that the contribution of P fertilisers to P build-up, even in surface water bodies, is negligible.

LIKELIHOOD OF NITRATE–NITROGEN LEACHING

As indicated earlier, breakdown of soil organic matter to yield nitrate is a normal feature of the soil biological cycle. Herlihy *et al* (Morgan, 1983) have indicated the potential for nitrate production that is possible in the field, and also the similarity in vertical movement in the soil of soluble N derived from organic matter only compared to that which is derived from organic matter + N fertiliser. Thorough mixing of the soluble N from the two sources is therefore indicated. Seasonal pattern of nitrate production which, with nitrate already present from a fertiliser application, results in an oversupply of nitrate to the growing crop, will add to the risk of nitrate loss. Likewise, Autumn production of nitrate from organic matter, either in the absence of growing crops or when followed by a period of poor growth, will also add to the capability for nitrate leaching. Obviously, too, potential for nitrate leaching loss will also be influenced by the quantity of nitrate that becomes available from fertiliser sources and by the time of application of the fertiliser.

Extent of nitrate leaching is directly related to the amount of rainfall that is available to "wash" the mobile nitrate downward. On the other hand, the magnitude of nitrate loss is inversely related to the amount of uptake by the growing crop and also to the amount that might be lost from the soil by denitrification. Risk of downward nitrate movement is greater in sandy soils than in those of heavier texture, while tillage, because of relatively inefficient uptake of added N (ca 50%) is also at greater risk than grassland (ca 70% efficiency). The composite picture that emerges from all of this is that the quantity of nitrate reaching a particular water body in the course of a year, say, derives from a number of sources, including fertilisers and soil organic matter, and that this amount is determined by the outcome of the interaction between a large number of factors. However, because of the changing influence of these factors on a year to year basis, it is not possible to invoke a 'universal theory' to account for, or predict, the relative contributions from each source.

An extensive series of trials conducted by Sherwood *et al* on grassland sites at Johnstown Castle has been summarised by Morgan (1983). In general, these studies suggested that an annual N application of ca 250 kg/ha was necessary before significant (10–12 ppm N) movement of nitrate to depths greater than 1m occurred. Reasonably, it can be expected that some of this nitrate will move laterally in the soil to surface water courses while some will also undergo deep percolation to the ground water. In the following analysis an annual rate of application of 250 kg/ha is taken as the value below which significant movement of nitrate to water will not occur. While a similar 'safe' rate of fertilisation has recently been reported for grassland in England (Barraclough *et al,* 1983), the above discussion emphasises that a single critical rate may not be generally applicable across the country.

ANALYSIS OF NITROGEN FERTILISER USE IN IRELAND

Table 2 shows the land use pattern in each of the four provinces for 1980. Clear regional differences are evident with Leinster and Munster, together, providing much the larger proportion of land in the categories 'tillage', 'hay + silage' and 'pasture' (90, 70 and 66%, respectively). Thus, it can be safely assumed that the bulk of the total volume of N use is confined to the east, south and south-east. Two questions arise from this: (a) what are the rates of N fertilisation on land used for different purposes, and what is the extent of regional difference in rate of use for the same purpose? and (b) are the rates used generally acceptable from the standpoint of nitrate leaching? These questions are less relevant to tillage than to grassland because tillage represents only 10% of the total agricultural area of the country. In addition, tillage crops across the country tend to be uniformly fertilised whereas grassland is fertilised on varying degrees according to the particular system that is followed.

TABLE 2
Area (000's ha) of land in different use categories in each province in 1980[1]

Region	*Tillage*	*Hay incl. Silage*[2]	*Pasture*	*Rough Grazing*	*Total*
Leinster	331	364	874	118	1,687
Munster	163	488	1,058	394	2,103
Connacht	33	240	711	341	1,325
Ulster	28	122	289	157	596
Total	555	1,214	2,932	1,010	5,711

(1) Anon (1983); (2) includes small areas in ryegrass seed

TILLAGE

Fertilisation of tillage crops with N is based on national recommendations (Anon 1982) that may be adjusted according to the presence in the soil of old crop residues or additions of animal manures etc. An approximate test of whether actual use corresponds with recommended use is given in Table 3 which compares mean N recommendations for four tillage crops with actual (apparent) use. The four crops shown collectively account for ca 80% of the national tillage area, and the actual use-data were obtained from a national fertiliser use survey (Murphy, 1983). It

TABLE 3
Actual (1979)[1] and recommedned rates of nitrogen use on selected tillage crops (kg/ha)

Crop[2]	*% of national tillage area*	*Actual*	*Recommended*
443 Feeding Barley	57.2	62	75
616 Potatoes	7.5	94	121
70 Sugar Beet	6.0	157	108
51 Wheat	9.6	83	80

(1) Murphy (1983);
(2) numbers preceding crop refer to number of farms in survey on which the crop was grown.

appears, then, that only sugar beet was excessively fertilised. In assessing the environmental impact of this, it could be argued that the large area of barley (ca 317,000 ha) that appears to be underfertilised would compensate for the apparent over-use of N on sugar beet. While beet occupies only 6% (33,000 ha) of the national tillage area, 43% of the beet grown in Leinster takes place in Wexford while 73% of the Munster production takes place in Cork. A considerable concentration of the crop in these two counties is therefore indicated, suggesting at the least an unnecessary degree of 'local' risk. Similar remarks also apply to a small area of dessert apple orchards in Kilkenny/Waterford that has been found to be excessively fertilised (Morgan and Hennerty, 1976). The overall conclusion that may be drawn from this analysis, however, is that the national tillage area is not excessively fertilised with N.

GRASSLAND

It is not possible to conduct the same exercise with grassland as with tillage mainly because of lack of information on the areas of land devoted to one grassland system rather than another. Nevertheless, data are available (Table 4) which show the general level of N use on each of the three classes 'hay', 'silage' and 'pasture'. Espec-

TABLE 4
Mean regional use (1979)[1] of N on hay, silage and pasture (kg/ha)

Region	*Hay*	*Silage*	*Pasture*
Leinster	52	103	62
Munster	47	105	67
Connacht	33	73	16
Ulster	53	97	34

(1) Murphy (1983)

ially in the case of pasture, it is apparent that there is significantly less N used in Connacht and Ulster than in Leinster and Munster while consumption on hay and silage is also apparently much less in the western counties than elsewhere.

Of the categories of grassland shown in Table 4, pasture is by far the most significant, amounting to ca 50% of total land area in each province or ca 70% of the grassland area in each province when the appropriate areas in 'rough grazing' are discounted (Table 2). Examination of the rates of N use in this category, then, provides a critical test of the intensity of fertilisation in the country as a whole. This information is presented on a county basis in Table 5.

TABLE 5

Utilisation (1979)[1] of N on pasture in Ireland (kg/ha)

County	*Rate*	*County*	*Rate*
Carlow	61	Clare	29
Dublin	51	Cork	105
Kildare	67	Kerry	38
Kilkenny	75	Limerick	73
Laois	56	Waterford	99
Longford	33	Tipperary NR	51
Louth	139	Tipperary SR	75
Meath	42	Galway	26
Offaly	49	Leitrim	6
Westmeath	28	Mayo	14
Wexford	84	Roscommon	15
Wicklow	53	Sligo	18
Cavan	43		
Donegal	16		
Monaghan	43		

(1) Murphy (1983)

Referring to the questions posed at the start of this section, and taking pasture fertilisation as the index, the rate of N use is in the range 6 (Leitrim) to 139 kg/ha (Louth), and there is clearly appreciable regional variation. There is, however, little or no evidence that the general use of N in any category of grass is as high as the rate that appears from Sherwood ***et al*** to be 'safe' i.e. 250 kg/ha.

FERTILISER USE AND SURFACE WATER RESOURCES

As has been emphasised already, it is virtually impossible in any body of water to separate the individual nutrient contributions that may arise from a variety of sources without making direct measurements on each source. The data in Table 5, however, allow a simplistic assessment, on a county basis, of the degree of association of N use with reported increases in the nitrate-nitrogen concentration of rivers (Lennox and Toner, 1980). This association may be summarised as follows:

a) increases (33–141%) in the maximum nitrate concentrations in six river stretches occurred in Cork, Louth and Louth/Monaghan where N fertiliser use is 'high'.

b) five stretches with increases in nitrate concentration ranging from 45–91% occurred in Longford, Meath, Mayo, Galway and Clare, counties in which N fertiliser use on pasture is considerably lower than the overall national average, and

c) in Kildare, Dublin, Limerick and Louth where N use on pasture varies from 51–139 kg/ha, there were seven stretches in which nitrate maxima either decreased or else showed only modest (10%) increases.

Even if all other possible sources of nitrate were disregarded (e.g. domestic, industrial, soil organic matter etc.), the foregoing argument does not suggest a causal relationship between current N use and nitrate content of rivers.

A similar conclusion can be made in the case of lake pollution. Since affected lakes are mainly located in the midlands, west and north-west, it might be expected (assuming a large effect of fertilisation) that areas (counties) drained by these lakes would be excessively fertilised. Such, in fact, is/was not the case and Offaly, Westmeath and Longford, as well as the western and northern counties and are/were all fertilised at a lower rate than any other area (Table 5). Significant N (or P) leaching in these circumstances is/was, therefore, highly unlikely.

CONCLUDING REMARKS

The general arguments presented here in respect of N and P use refer to 'normal' fertiliser-use practices and take no account of local cases of over-use or mis-use of fertilisers. The apparent lack of relationship between present use of N and nitrate content of water should only provide short-term comfort, for it cannot be assumed that the nitrate in land that has not been recovered by crops will not, in time, find its way to water. This notion is particularly important in relation to deep percolation of nitrate and contamination of ground water. Otherwise, the reality of the situation is that there is a finite rate of N use above which nitrate leaching will, indeed, become significant. The present position in Ireland is that this rate has not, yet, been reached.

The key to minimising nitrate loss from land is to maximise uptake of N by the harvested part of the growing crop. Especially in the case of N, some of the factors that influence leaching cannot be controlled, e.g. texture of the land and rate of intensity of precipitation. To a large degree, rate of decomposition of soil organic matter is also beyond control. There are other aspects of feriliser use, however, that can be controlled, with advantage to all sectors. These include (a) strict use of the quantities of fertilisers that are recommended for particular situations, with correct adjustments for the amounts of N that soil organic matter is likely to make (at the present time, there is some evidence of over-fertilisation of small areas of tillage, and the notion 'the more the better' still obtains to a certain degree), (b) the use, as commonly as possible, of smaller, more frequent applications of N to grassland and (c) avoiding early or late applications of N when neither rainfall nor temperature are conducive to maximising uptake. It has been estimated (Morgan, 1983) that attainment of 'medium' intensification of grassland farming in Ireland requires an increase of 67% or so in N use and that this increase can be assimilated without undue risk to water quality. Part, at least, of the 'undue risk' qualification depends on management aspects of fertiliser use.

In some respects, public perception of damage to the environment arising from an expanding fertiliser trade presents as much challenge to the agricultural sector as does actual damage that may occur from time to time. In this regard, attention is drawn to Table 6 which presents some statistics of N fertiliser use in Ireland for 1974, 1977 and 1980.

TABLE 6
Consumption (kg/ha)[1] of N fertilisers on agricultural area (A) and arable land/permanent crops (B)

	A			B		
Country	*1974*	*1977*	*1980*	*1974*	*1977*	*1980*
Ireland	23	40	47	130	234	283
Germany	96	107	127	158	176	207
Netherlands	208	217	239	518	517	561
United Kingdom	50	64	67	130	169	177

(1) Adapted from Anon (1980)

The values shown are taken from the FAO Fertiliser Year Book (1981) and Germany, Netherlands and the United Kingdom are included for comparison. On the basis of N use "per ha of agricultural area", it is apparent that Ireland has lagged behind each of the other countries shown. However, where the data are expressed as "per ha arable land and permanent crops" it appears that the rate of N use in Ireland was much greater than that in Germany or the United Kingdom while the difference in rate of use between this country and the Netherlands has narrowed considerably. The point at issue here is the value that is used to define each of the two land bases. Thus, there is close agreement between the value "47 kg/ha of agricultural area" for 1980 (Table 6) and the value obtained by dividing total N use in 1980 (0.2475m t) by total agricultural area (5.7 m ha). It is not clear from the FAO, however,how "283 kg/ha arable land and permanent crops" was calculated. By deduction, it seems that the land base used here was the area of land in tillage (0.554 m ha) + the area (0.294 m ha) under 'first to fourth year's hay' (Anon, 1983) i.e. 0.2475 m t divided by 0.884 m ha = 283 kg/ha. Quite clearly, this latter method of computation is grossly misleading since it disregards ca 5 m ha of agricultural land. The danger(s) of such an erroneous set of statistics being used in a prejudicial manner are obvious.

Within the agricultural sector, there is a general belief that increased output in the future will necessitate the use of more and more fertiliser. At present, the use of artificial fertilisers has not been as prominent in the public mind as has land spreading of animal manures. This, then, may be the appropriate time for a critical appraisal of fertiliser-use policy. In particular, the question arises as to the lack of flexibility in nutrient application that results from the use of compound fertilisers. Can a unique nutritional role be ascribed to all of the compound fertilisers currently on the Irish market? If "no", why have them? If "yes", are they being used for the proper purpose? Are present fertiliser recommendations sufficiently comprehensive to cover the range of fertility levels in Irish soils? In which sector is the sought-for expansion in fertiliser use to occur? Having due regard to environmental quality, there is a limit to which fertiliser use can be increased without adverse consequences. Obviously, this limit will be reached much more quickly if increased consumption is to occur largely in those areas of the country that currently consume the bulk of annual fertiliser sales. The inference here is that increased consumption should be distributed over as large an area of farmed land as possible. In the short term, this is the challenge for the fertiliser industry and the agricultural advisory service. In the longer term, the issues of land policy, land-use policy and 'incentive' need to be rationalised.

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