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ARE FERTILISERS POLLUTANTS?

An Appraisal with Reference to Indian Conditions

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Abstract

With the development of intensive agriculture in the country, the consumption of fertilisers, pesticides and other agricultural chemicals will increase sharply. Does the intensive use of fertilisers pose a pollution problem in India? Considering the fate of applied nutrients—nitrogen, phosphate and potash—from fertilisers to soil and their present level of consumption per hectare of agricultural land in the country, the chances of fertilisers polluting our environment seem to be very rare. The major and a serious source of environmental pollution could be soil erosion, a process depriving the country of one of man's greatest natural resources. Even the research carried out in developed countries shows that it is more the city sewage and industrial effluents which are polluting environments and not fertilisers which are often attacked by the scared environmentalist. In the paper, the author reviews in depth the vital question of intensive fertiliser use and environmental pollution with a special appraisal of the situation in India.

The breakthrough in wheat, rice and maize production that are being achieved by green revolution in a number of countries could not have been realised without the application of heavy doses of fertilisers. A great expansion in production and application of chemical fertilisers is needed in the developing nations in the next decade if these nations are to feed their population and to revolutionise their agriculture. Dr. Norman E. Borlaug in accepting his Nobel Peace Prize in 1970 made a strong point of the fact that if the dwarf wheats evolved by him were vehicle, the fertiliser was the fuel to this vehicle, which produced high yields and triggered off wheat revolution in many developing countries.

The question before us is whether fertilisers are at fault for causing pollution of environments. In case this allegation is correct, we must tighten the management of fertiliser use and revolutionise its recommendation. But if agriculture's contribution of plant nutrients to the environments has been over-stated then agriculture has the responsibility to set the records straight with facts and objectivity.

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Unfortunately, in the case of fertiliser use as in the case of pesticide use, the rhetoric of the hysterical environmentalists is clouding the basic problems. In view of the crusade which is being carried out by the environmentalists about the agrochemicals, doubts are being created in the mind of the farming community and the planners regarding fertilisers as well. It is, therefore, very essential for us to examine the situation regarding fertiliser use. Much of the problem in gaining a perspective on the whole pollution problem is to wade through the emotionalism associated with the subject and the conflicting data.

Nitrogen

Of all the essential plant nutrients, nitrogen is universally limiting plant growth and development. With nitrogen, it is not a fact that it degrades the land but rather that nitrogen in soil seems to be a sink from which nitrogen enters in our ground and surface water either indirectly through animal consumption and decomposition or directly through run-off and leaching. In order to ameliorate the problem associated with nitrogen in soil, it becomes necessary to evaluate some of the reactions and movements of nitrogen in soil with a view to predicting and preventing this unwanted entry in our water supplies. There are five basic reactions which nitrogen undergoes in soil:

(i) Can be incorporated into organic matter through utilisation by soil micro-organism;

(ii) Released from unusable organic forms into inorganic ones;

(iii) Be transformed into inert gas formed by soil micro-organism, such as denitrifiers;

(iv) Be moved out of the root zone of the plant by leaching; and

(v) Be removed through crop utilisation.

The leaching of nitrogen, phosphorus and other nutrients in soil has been investigated by a number of workers by collecting and analysing water from either the drain or using the lysimeters. Most of the soil research on nitrogen has been on the leaching loss of nitrate nitrogen, ammonium nitrogen and nitrite nitrogen. Some work has also been done on the reaction of other nitrogenous forms. Results of lysimeter studies in California and New York showed that nitrate is the predominant form of nitrogen in percolating water and more than 99 per cent soluble nitrogen was in the nitrate form although under certain circumstances appreciable amount of ammonium and organic nitrogen including urea can be found in the leachate. Less than 1 per cent was found as ammonia and only traces as nitrite. The explanation for low nitrite level was that only a small concentration was present in the soil while the low loss of ammonium was attributed to fixation by colloidal exchange complexes. Usually, all the nitrogen in the leaching water is in nitrate form and the ammonium form is either held by colloidal exchange complex or oxidised to nitrate by microbial action and then lost. In peat soil, a large amount of ammonium nitrogen was found in the water in the leachate which was attributed to the reducing power of the peat. More recent work confirms earlier findings that applied nitrogen in the nitrate form is easily and generally completely removed from the soil profile by percolating water. Tisdale and Nelson (20) found relationship between nitrate movement and amount of percolating water and soil porosity by multiple regression analysis of the data from column leaching studies in eight course textured soils of North Carolina. The relationship was

$$Y = 1121.98 + 64.66\ x_1 + 5.83\ x_3.$$

Y = Nitrate movement of nitrate in cm.

x_1 = porosity index of soil and x_3 porosity index time amount of water added.

Movement or leachability of organic nitrogen compounds is a function of two parameters: (a) case of absorption; (b) water solubility. Organic N containing herbicides, such as Simazine and Atrazines are not very mobile in soils. They are generally not leached beyond 4-6 inches. That the loss of fertiliser N does indeed occur from the soil is an undeniable fact of a progressive agriculture. However, the magnitude and possible consequences are currently the basis of controversy.

The ecologists feel that nitrate (NO_3) losses in leaching ground water or through surface run-off are contributing significantly to pollution of environments. This in turn is related to increased eutrophication of lakes, streams and water reservoirs and to potential health hazards to human beings, particularly to infants (blue babies) and livestock, particularly ruminants, which might consume surface and ground waters containing excessive amount of nitrate. They also charge that high nitrate content of vegetables is related to excessive use of fertiliser N, which causes health hazards, particularly in baby foods.

The agriculturists, on the other hand, contend that increase in nitrate content of ground waters, streams and lakes in the vicinity of heavily manured areas is not a sufficient proof that fertilisers are more significantly contributing factors. dence that sources of nitrate other than fertilisers are more significantly contributing factors. The most important are: (i) untreated sewage effluent; (ii) animal wastes, particularly from the modern large-scale animal sheds; (iii) food processing wastes; (iv) industrial effluents; (v) biological N fixation in aquatic environments; (vi) mineralisation of soil organic N; (vii) movement of water through high nitrate containing geological formations; and (viii) N loss from soil erosion.

The support for this view comes from a number of excellent reviews (1,21,22). However, it is not denied that NO_3 loss in drainage water or leaching water can be measurable if the soil is excessively fertilised, poorly managed and kept u[illegible]opped for some time. Unfortunately, properly documented critical information on the loss of nitrate N from the soil does not exist. Such an information needs to be collected from controlled plots of water sheds where an account could be kept of all the losses of N in drainage water, run-off water and the contribution by different factors.

Viets (21) while discussing the last 30 years' data concluded that almost universally the experiments have failed to determine how much of the fertiliser percolated below the root zone. Viets and Hageman (22) have concluded that the rate of water recharge from ground waters is so slow that the possible nitrate pollution of aquifires from our modern technology will take decades. Lysimetric studies in Gujarat show that the amount of N lost in leaching for 90 cm soil depth of Goradu soil was 14 kg/ha out of 180 kg N applied. Patnaik (14) could not account for 23.45 per cent N after 75 days of application and attributed it to oxidation, leaching and denitrification. At the Central Coffee Research Institute a loss of 31-42 kg N, 1.5-2.2 kg P and 6.6-8.8 kg K were leached annually under a rainfall of 2,750 mm.

Bingham *et al* (4) evaluated the nitrate leaching losses from an irrigated 384 hectares citrus water-shed in California which received annually 144 kg N/ha. It was observed that 45 per cent of the N was lost in the effluent drainage water from a continuously and excessively fertilised and irrigated gravely soil with a low retention capacity and high degree of slope.

Olson (12) reported the following values of NO_3 nitrogen in the surface 6.5 meters of soil and in the ground water (Table 1).

TABLE 1: Nitrate content of groundwater as affected by land use pattern.

Land use	Nitrate in 6.5 meters of soil	Groundwater NO_3 nitrogen
	kg/ha	ppm.
Native grass land	101	11.6
Dry Farming crop land	294	7.4
Irrigated land excluding alfalfa	569	11.1
In alfalfa	89	9.5
Feed lots	1,616	13.4

It shows that the highest concentration of nitrate in water came from feed lots.

In view of the above background, it is necessary for us to examine whether fertilisers could be blamed for environmental deterioration or pollution of our waters and other health hazards. For properly evaluating this problem one has to take into consideration many facts. The next question to answer is what happens to nitrogenous, phosphatic and potassic fertilisers when they are added to the soil. It will throw some light on likelihood of any damage to environments.

Nitrogenous fertilisers: It has been estimated that 90 million metric tons of N are fixed biologically on this earth annually through algae in water, bacteria on land and an additional 10 million tons through rainfall. This 100 million tons is nearly four times the total production of nitrogenous fertilisers (25.6 million tons N) in the factories for use in agriculture in the world. Thus, the major amount of N entering the soil today is still through the biological means. Nearly three-fourths of the total N produced industrially is in the developed countries. The question of nitrogen losses in leaching can be understood if one studies the fate of nitrogenous fertilisers to the crop.

Nitrogen recovery by crops: Of all the nitrogen applied as a fertiliser, major part is removed by the crop, depending upon numerous factors, such as, nature of crop, amount, time and method of application of the fertiliser and management of soil, water and crop. The data from lysimeter experiments in U.S.A. and U.K. as reviewed by Allison (2) revealed a recovery of 21-79 per cent. The values of recovery were above 60 per cent with grasses. In pot experiments, the values of recovery have ranged from 30 to 92 per cent. The experiments with N^{15} have also confirmed similar results.

In field experiments the recovery of applied N is generally below 50 per cent (2, 3). Rice crop has reported some of the lowest recoveries. Some of the values reported by Indian authors (13) are given in Table 2.

From this, it is evident that depending upon many factors, about half of the N applied to the soil is available for loss through (i) volatilisation;

TABLE 2 : Nitrogen recovery

Crop	Source of N	Rate (kg/ha)	Percentage recovery	Location
Wheat	Am. sulphate	60-140	34-39	New Delhi
		126	27-35	U. K.
Corn	Am. sulphate	80-240	35-75	New Delhi
Sorghum	Urea	120	58.5	New Delhi
Rice	Urea	150	34.3	New Delhi
	Am. sulphate	40-120	39.6	New Delhi
	Urea	180	10-30	Peru
Rice	Am. sulphate	50	41.2	Ludhiana
		200	59.2	"
	Am. sulphate	200,50	62,22.3	Brazil *
	"	200,50	38,13.7	Rumania *
	"	200,50	47.2,17.9	U. A. R. *
	"	200,50	60.4,26.7	Cambodia *

* Data from Rice Fertilisation (1970) published by International Atomic Energy Agency.

(ii) denitrification; (iii) fixation as ammonia in the soil; (iv) conversion to organic forms through micro-organism; (v) loss through run-off; and (vi) loss through leaching.

The distribution of the nitrogen in these forms is the subject shrouded with lot of conflicting and non-critical data. Conditions which favour greater recovery of N by the crop will be favourable for least loss of N through leaching. There is evidence in India that some of the residual N applied to maize benefits subsequent wheat crop. Similar residual effect has been observed in many other crops.

A study by International Atomic Energy using N^{15} has shown that N loss in gaseous form varied from 28 to 64 per cent. With the method of surface application the utilisation percentage ranged from 23.3 to 45 per cent in many rice growing areas.

Does the N loss cause eutrophication: Because N is present everywhere (about 79 per cent in the atmosphere) and it is a very mobile element in water, air and land, it has received very wide attention in recent years with respect to eutrophication or unwanted growth of algae. If one remembers that 40 species of algae absorb N from the air, it does not seem to be likely that N from fertiliser can be considered responsible for the eutrophication of lakes and other water bodies. It is also a fact that 0.3 ppm N or half of this in ordinary rainfall is enough to support algal growth.

Stanford *et al* (16) and Olson (12) have attempted a balance-sheet of N for U.S.A. (Table 3).

From the results given in Table 3, it is evident that even in developed countries like U.S.A., the major loss of nitrogen is through soil erosion and through loss of native N from soil. There is no exact estimate of nitrogen loss derived from fertiliser N, though it is anticipated that as fertiliser N consumption increases, N loss in drainage water will also increase.

TABLE 3: Balance-sheet of N in harvested cropland in U.S.A.

Particulars	N million tons/annum 1947	1969	1980
Input of N from			
Fertiliser N	0.7	6.8	12.2
N fixed by legumes	1.7	2.0	2.5
N fixed non-symbiotically	1.0	1.0	1.0
Farmyard manure	1.3	1.0	0.9
Roots of harvested crops	1.5	2.5	3.0
Rainfall	1.0	1.5	1.8
Total input of N	7.2	14.8	21.4
Removal of N by			
Harvested crops	6.5	9.6	13.0
Erosion	4.0	3.0	2.0
Leaching of original soil N	3.0	2.0	1.5
Leaching of fertiliser N	0.0	?	1.2
Denitrification	?	?	2.2
	13.5	14.5	19.9

TABLE 4: Nitrate profile under different treatments for different cropping histories.

Sample	Nitrate content (ppm) in the soil profile			
	Irrigated straw-berries	Uncrop-ped 5 year	Irrigated celery	Perma-nent pasture
2 Feet		<1	14	56
4 Feet	2.7	1.4	25	<1
8 Feet	3.6	4.3	—	—
16 Feet	2.5	3.7	—	—
24 Feet	1.6	4.8	15	<1

The effect of different cropping history on nitrate content of the soil at various depth has been studied in the U.S.A. Interestingly enough under the heavily fertilised strawberry crop, there was no evidence of NO_3 build up to lower horizons of soils. Similar was the case with celery and permanent pasture. The loss of nutrients particularly of nitrogen through erosion is enormous. It is also affected by cropping system. Bhatt and associates (5) from Dehra Dun have reported that from run-off plots in Dhulkot silty clay loam soil the run-off loss of soil and plant nutrients was maximum from maize-wheat rotation as is evident from Table 5.

Bower and Wilcox studied the effect of N fertilisers on N content of irrigation and drainage water of the upper Rio Grade River and concluded that in 30 years period there was no demonstrable change in nitrate content of the drainage water despite continuous use of fertilisers in the water shed (Table 6).

TABLE 5: Nutrient losses under different cropping systems

Treatment	Nutrient loss kg/ha			Available	Available
	soil loss	organic carbon	N	P_2O_5	K_2O
	(tonnes/ha)				
Sunhemp-wheat	31.7	286.1	40.3	12.1	12.7
Jowar-wheat (Fodder)	49.3	370.3	53.1	10.7	19.0
Maize-wheat	76.1	538.4	79.2	17.7	28.1
Grass	—	Nil	Nil	Nil	Nil
Fallow (Cultivated)	291.0	2,167.7	228.1	70.5	98.5

Effect of fertilisers on food quality: Nitrogenous fertilisers generally are known to improve the protein content of the grain and forages. By properly timing the application of N one can affect the N content of the plant tissues. The heavy use of nitrogen fertilisers on crops when the leaf is consumed (salads) can, however, have an undesirable effect. If N is applied near maturity, the crop may not have time to metabolise it and it may remain in inorganic form which may be injurious.

Heavy nitrogen use can have a number of undesirable consequences. It increases the susceptibility of the crop to diseases and pests and may lower the storage quality of the product. In case of potato, it lowers the cooking quality. In cigarette tobacco, the quality of leaf is adversely affected by high nitrogen.

Though there is a fear of high nitrate content in food on human health, according to World Health Organisation, there were no reported cases of nitrate poisoning due to nitrate rich foods.

If the N content reaches 0.3 ppm and P content 10 ppm, the algae and the other aquatic weed growth is encouraged in a clear water. In India in some lined canals the algal growth becomes quite significant despite the fact that there is no source of enrichment with N. It seems that the N from the atmosphere is being utilised by the algae.

Indian experience: The hazard caused by fertiliser should be proportional to the amount used per acre or amount used per capita. From Table 10, it may be seen that India is using only 6.15, 1.45 and 0.92 kg N, P_2O_5 and K_2O respectively per hectare (according to 1969-70 statistics) which is hardly 1/47th that of the fertiliser consumption per hectare in Japan. When we compare it on per capita basis the amount is hardly 2.6 kg. It shows that not only India is using the least amount of nutrients per hectare but also per capita. If the use of such large quantities of

TABLE 6: Nitrate concentration of irrigation and drainage water

Irrigated area	Pnriod	Irrigated water	Drainage water
		ppm	ppm
Rincon Valley	1934-43	0.15	2.31
	1954-63	0.12	1.61
Nasila Valley	1934-43	0.29	0.17
	1954-63	0.24	Traces
Elpass Valley	1934-43	0.24	0.44
	1954-63	0.12	1.03

fertilisers in Japan, Holland and Denmark has not produced any ill-effect on human health or any deterioration of quality of environment, it is very unlikely to do so in case of this country where the amount of fertiliser used is infinitesimally small. Moreover, even if a fraction of this fertiliser is lost through leaching or other biological activities, the effect on the environments will be hardly measurable but because of the monsoonal climate and paddy cultivation the loss of N can be high. The fact that during *kharif* season, the response to N is low in paddy soils arouses the suspicion that substantial amount of N is being lost in volatilisation and leaching. Drainage studies on heavily manured paddy field at CRRI, Cuttack, have revealed that during the *kharif* crop season, 42 kg N, 29 kg phosphorus, 38 kg iron and 17 kg manganese were lost. There was no separate record about nitrate content of the water. There are very few studies about the quantitative estimation of N losses in the gaseous form from submerged condition in paddy cultivation. Datta and associates (8) using N^{15} technique concluded that gaseous N loss was 24.1, 30.2 and 53.7 per cent in case of tagged ammonium sulphate, nitrophosphat (high water solubility) and nitrophosphate (low water solubility) respectively.

The loss of nutrients in gaseous forms as well as in drainage from heavily fertilised rice fields requires immediate and critical studies in India. Whether this loss of nitrogen adds any nitrate to underground water is a big question mark. The likelihood of it is rather small. However, critical studies are needed for formulating a sound policy of manuring of rice beyond a certain level. Likewise we need to know the interactions between organic manures and fertilisers for nutrient losses in paddies.

Phosphorus

Next to nitrogen is the consumption of phosphates in India. This consumption is also very low but is increasing gradually. Phosphate when applied to soil gets fixed up so rapidly that the loss of the nutrient in leaching water, could hardly be significant. Kohnke *et al* (11) in their summary of lysimeter work of 250 years indicated that only trace amounts of phosphate had ever been found to percolate. The authors also concluded that only in light textured soils which have been heavily fertilised would a small amount of phosphate percolate through the soil profile.

No doubt, the loss of phosphate from the soil in leaching water may be so small but the amount of P required in solution for the growth of algae is also very small. It is observed that P concentration in solution as low as 0.015 ppm is sufficient to support a nuisance growth of algae if other conditions are favourable. A concentration of 0.05 ppm. supports lush growth. The major loss of P from the soil occurs due to erosion, when the soil particles with phosphate occluded on the surface are mechanically carried by run-off water into streams, lakes and other inland water bodies and oceans. Thus this loss is natural and part of P cycle can be minimised by adopting proper soil conservation measures.

Movement of phosphorus in solution from soils:

In fine textured soils the downward movement of P is very small relative to the total amount of P present. Thomas (19) has calculated that given a soil solution concentration of 0.2 ppm. P and a total annual percolation of 51 cm of water, the phosphorus loss will be hardly 1 kg/ha per annum assuming complete equilibrium which is seldom possible.

In sandy soils, on the other hand, because of low clay content and low concentration of iron, aluminium, calcium and magnesium and soil pH depending on the nature of the soil, the phosphate loss can be more than in heavy textured soils. However, depending on a number of factors and management, the sandy soil could lose more amount of phosphate in drainage waters.

Organic soils have very low capacities to absorb phosphates and hence could lose considerable amount but this progress could be changed by treatment with lime, aluminium and other methods, as is evident from the data (Table 7) by Fox and Kampreth (9).

In flooded soils such as paddy soils, the solubility of phosphate increases by flooding because of hydrolysis of iron phosphates. Thus large contribution of P to stream and lakes can take place in such soils depending upon the hydrology of the area. There is very inadequate data in India on the leaching losses of P from the flooded soils because of the absence of controlled drainage systems.

From irrigated soils, depending upon the cropping system and management, the phosphate losses will vary. Johnson *et al* (10) reported that from tile drained soils in California, the phosphate losses varied with the crop and management, but the amount lost was ranging between 1 to 11 kg/ha. Carter *et al* (7) reported a nitrate phosphate study from 80,000 ha irrigated tract in Southern Idaho (U.S.A.). The authors concluded that irrigation decreased the phosphate load of the drainage water if the irrigation water contained more than 0.01 to 0.02 ppm. phosphate. The authors were doubtful if the phosphate loss in drainage water would be important.

Taylor (17) calculated that 1.1 to 5.6 kg P_2O_5/ha of eroded soil were annually lost in U.S.A., but how much this source contributed to normal aquatic environment was difficult to ascertain because of the continuous recycling and secondary reactions.

TABLE 7: Leaching of fertiliser P from a St. Johns soil related to chemical treatments

Teatment	pH	P leached (ppm)	P adsorbed (ppm)
Original soil	3.4	4.6	—
Original soil & P	3.4	14.5	0.1
H soil & P	2.5	16.0	0.0
Al soil & P	3.9	4.7	9.9
Ca soil & P	4.0	15.8	0.0
Limed soil & P	4.1	13.2	1.4

TABLE 8: Phosphate loss under different cropping systems.

Crop	P added kg/ha	Phosphate loss kg/ha/year
Fallow	0	0.04
Corn continuous	29	0.05
Corn rotation	29	0.05
Oats rotation	N-A	0.01
Hay rotation	0	0.23

The loss of phosphate from fallow soil is more than from cultivated soil as is evident from the results reported from Dehra Dun given in Table 4. Timmons *et al* (18) also concluded that the phosphorus content of run-off was influenced by different cropping practices in Minnesota. The results are given in Table 8.

Viets (22) stated that the nutrients contained in or absorbed on sediments were the greatest contribution of land to water. Fertilisers play an important role in this process. On one hand, they enrich the eroding particles; on the other hand, they can reduce erosion by contributing to better vegetable cover on the soil and increasing the products of land. The P content of the eroded material is generally higher than of the parent soil, resulting in higher enrichment ratio.

Non-agricultural contribution of phosphorus to waters: The greatest contribution of phosphates and other nutrients to surface waters results from sewage effluent and industrial wastes. In the developed countries, the human waste is very high. Wadleigh (23) indicates that human waste* in U.S.A. equals animal waste** which amounts to 1½ to 2 billion tons/year equivalent to 2¾ lb per capita per day. In developing countries like India animal waste is a source of fuel and manure. In developed countries, however, it is becoming a problem to use it because of the high cost of disposal. Moreover, as cattle industry is organised in very large units, the output of waste becomes huge. In fact, its disposal is becoming a problem. The loss of organic matter and nutrients like N & P from

* Waste produced by human beings.
** Waste produced by animals.

these units is very large. Moreover, because of the protein rich feed used for fattening and dairy purposes, the excreta is also richer in N & P than that in developing countries.

The human waste in rural India is seldom collected in an organised way but in advanced countries, it mostly goes to sewerage and compost. A survey of 11 developed countries showed that the amount of phosphate excreted by animals population and human population was on an average in the ratio of 11 to 1. The contribution of phosphorus by these sources to effluent water is very large.

Another rich source of phosphorus causing pollution is detergents. Most of the P in this form is discharged into sewage systems which invariably is the cause of eutrophication in many inland waters.

In the countryside in India, it may not be a serious problem but in big cities like Delhi, Calcutta, Bombay, Kanpur and Madras where concentration of population is very high it may become quite serious.

From the above discussions, it may be concluded that so far as phosphorus is concerned, fertilisers do not seem to be significantly involved in raising the P levels of surface waters and ground waters. On the other hand, by promoting vegetative cover they help in reducing erosion and thus reduce P loss to waters. The major source of phosphate loss is soil erosion which results in mechanical movement of potentially available P to streams and lakes. The contribution by human wastes and animal wastes, industrial wastes and detergents to P content of streams, lakes and marine and also inland waters is very substantial. Thus it is not the phosphate fertiliser but the organic sources of phosphorus which could be a source of pollution.

Potassium

Potassium is one of the major plant nutrients and is invariably applied to crops for obtaining good yields. The question is often asked if the K containing fertilisers add to the pollution problems. The potassic fertilisers are all water soluble and on application to soil undergo cationic exchange K replacing Ca and Mg and other ions. Thus K is present in exchangeable forms or gets fixed up in the clay lattices particularly illite and other micacears minerals. The crops also have unusual capacity of luxury consumption of the K in soil solution and exchange forms is present in high amount. The K fixing capacity of soil is so high that normal applications of K in fertiliser form seldom become high enough to become excessive. However, from sandy soils with low exchange capacity, there is some chance of loss of potassium. On clay and loam soils, it is unlikely that any appreciable amount will move more than 50-70 cm in soil. The K content of drainage water is usually less than 0.1 m.eq/litre. It is also observed that leaching into the sub-soil is less when the soil is fertilised. Even with 240 kg K_2O/ha the movement of K into the sub-soil was less by 30 per cent than in the same soil without K fertiliser if there is an adequate supply of N and other nutrients. It rather shows that from a poor and unfertilised soil there is a greater chance of K loss than from a rich soil, as is evident from the data given in Table 9.

Loss of K in erosion: Erosion is the most serious cause of K loss. In fact, because of high content of K in the soil the eroded material has more K than N and P but the recycling process is so strong that K seldom enriches the water.

Secondary Nutrients

Compounds are mostly added in the form of liming materials for correcting soil acidity and counter balancing the nutrient loss from humid and acid soils. Though the loss of secondary nutrients from soils is quite high particularly under high rainfall conditions, there is no evidence that they cause pollution. Magnesium loss in certain areas has been responsible for tetany in cattle. The loss of SO_4 in the sandy soils is very high.

TABLE 9: Leaching of K from different depths from fertilised and non-fertilised soils.

Fallow	0	0	57	3
Oats	0	0	55	3
Oats	59	123	45	13
Oats	117	182	51	2
Oats	176	240	41	2

Micronutrients: The micronutrients such as Mn, Zn, B, Mo, Cu, Fe and Cl are considered essential for plants. The cases of certain micronutrient deficiency are well established. In India very large areas are deficient in zinc and this deficiency is also accentuating with intensive cropping and heavy fertilisation. There is evidence that much of phosphate accentuates zinc deficiency. Because of antagonism between different micronutrients, any ad hoc application of unwanted nutrient will also affect the balance, hence availability of the others. The micronutrients are so strongly absorbed in the soil that there is little likelihood of their going into the drainage water. On the other hand, the change in soil conditions, redox potential results in movement of Fe and Mn, which have been traced in the drainage tile lines.

The movement of micronutrients with the organic matter is very high as complexes. Thus, the effluent from the urban areas is a rich source of contamination with micronutrients.

The eutrophication process, which is causing so much scare in the world besides N, P, CO_2 requires molybdenum (Mo) besides other nutrients for the growth of the algae. There is little evidence that Mo from farm lands could become a source of this pollution.

What are the Facts about the Contribution of Fertilisers to Pollution?

In trying to find answers to water pollution problems some ecologists have placed blame on use of chemical fertilisers and have overlooked the numerous other sources of pollutions.

1. A certain amount of recycling takes place every day in nature regardless of what we do or don't do. The decomposition of plant and animal waste is a part of a nature's way, to maintain plant, animal and marine life on earth. Man only speeds up these processes.
2. Rainfall itself contributes significant amount of nutrients and its contribution will depend on the industrial pollution of the air. In developed countries the contribution of NO_3, SO_2 and CO_2 from the rain is very high.
3. Run-off and soil erosion is a major cause of pollution in nature and any activities which accelerate erosion also accelerate pollution. In developing countries, soil erosion is a serious factor and encroachment on marginal land and use of land regardless of principles of conservation is causing a havoc. The loss of nitrates in the presence of a growing crop is less than in a bare and fallow soil. This also shows that with intensive cropping and keeping the land all the year round under crops will have least hazard of nutrient losses. The situations most conducive to nitrate leaching are when rainfall exceeds transpiration. Thus, it is more serious in humid than arid areas. Leaching of nitrates from unfertilised but soil of high fertility is more than from fertilised lands of low fertility. In other words, so far as the developing countries are concerned, use of fertilisers will seldom be a cause of pollution.
4. Every student of soil science is familiar with the long term fertiliser experiments in many countries including India. There is no evidence that balanced use of fertilisers has affected the soil productivity adversely. On the contrary, all the available evidence shows that as a result of continuous fertiliser application nations have improved the fertility status of their soils and increased annual production per unit area. The developed countries have been able to revert millions of acres for recreation, forestry and non-agricultural purposes, by intensifying agriculture through fertiliser use on less acreage.

In India, in view of the changed conditions and new technology, a new series of long term experiments to study the effect of fertilisers, manures, pesticides, irrigation and intensive cropping have been started. They will provide the necessary information for correcting any policy with regard to the use of agro-chemicals for different situations.

What is the Position in India?

As mentioned earlier, India uses (Table 10) hardly 1/47 to 1/81 as much fertiliser as a developed country like Japan and Holland respectively. There is, therefore, little fear of any pollution from use of fertilisers as such. However, excessive use of nitrogenous fertilisers should be avoided. The inefficient use of fertilisers and manures and poor soils and poor water management can result in lower efficiency of nutrients and pronounced losses. It can be more serious in humid areas and in sandy soils with low exchange capacity and low buffering capacity. The inadequate use of fertilisers results in less vegetative cover and accelerated erosion which is a serious cause of pollution.

The pollution of the environment from the city effuents and town's wastes can be serious cause and needs to be watched. It is more a problem of health and sanitation measures and disposal of the wastes.

The rural areas suffer loss of nutrients by leaching or run-off from farmyard manure stacked in the open or carelessly spread. It is a general practice that farmers spread bulky organic manures on the fields, a few days before the onset of the monsoon. Unless, it is properly incorporated into the soil before the rains, it is likely to be lost by run-off and thus become a dead loss to the farmer. Quite often, the poor results from experiments with such manures are due to this fact.

The most significant cause of pollution from the agricultural lands is through soil erosion. Not only the nation is losing millions of tonnes of nutrients every year, it is threatening the whole environment, our costly irrigation projects, cities, habitations and life. It is estimated that India is annually losing 6,000 million tonnes of soil from 91 million ha which are reported to be suffering from erosion problem. Assuming that from a soil of 0.5 per cent slope, the loss of nutrients as 5.8 kg N, 10.7 kg. P_2O_5 and 42.8 kg K_2O/ha, the minimum annual total loss from Indian soils would amount to 2.5, 3.8 and 2.6 million tonnes of N, P_2O_5 and K_2O respectively which is much greater than the present total consumption of NPK from fertiliser as well as organic manure sources. Moreover, there are millions of hectares which lose many times more nutrients per hactare because of greater slope and greater erodibility.

No doubt, we cannot remove this loss altogether, but we can certainly minimise it. Thus, for a developing country like India, there is no danger from the use of fertilisers, rather there is a greater danger from the absence of its use as it would mean lower productivity of land thus necessitating extension of agriculture to marginal and more vulnerable lands and accelerated rate of erosion. Thus, fertiliser is the savior of our environment and not a pollutor as some are trying to pose in the developed world, but we should not have any complacency and should take all steps to maximise the losses of nutrients. It calls for intensive research and educational programmes commensurate with the magnitude of the problem.

TABLE 10: Fertiliser consumption per hectare in relat. to arable land and population—1969-70.

Continent/ Country	N	P_2O_5 Kg/ha	K_2O	Nutrients, kg/ha	Per capita consumption of nutrients
Netherlands	431.85	120.71	138.06	690.02	47.80
Belgium	206.26	166.86	216.91	590.06	81.20
Japan	160.09	123.04	123.15	406.28	22.25
U.K.	89.46	63.41	63.56	216.43	28.30
U.S.A.	38.35	23.49	20.75	82.59	70.71
India	6.15	1.45	0.92	8.52	2.60
World	19.56	13.60	11.85	45.01	21.20

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