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INTEGRATED ENVIRONMENTAL PROTECTION DESIGN AND SUCCESSFUL IMPLEMENTATION AT KEMIRA SIILINJÄRVI SITE

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RESUME

Cette présentation met l'accent sur les aspects intégrés de l'environnement (effluents dans l'air, dans l'eau et sur terre), dont il a été tenu compte dès le stade de choix et de planification du site de Siilinjärvi.

En 25 années d'expérience opératoire, l'essentiel des critères choisis s'est montré convenable et crucial pour satisfaire les objectifs locaux stricts de qualité de l'environnement. Le site de production de Siilinjärvi comporte une mine de phosphate, un atelier d'enrichissement, des ateliers d'acide sulfurique et d'acide phosphorique et des unités d'acide nitrique et de NPK

Le site est situé sur un lac entouré de forêts de conifères sensibles à la pollution. Les autorités locales de protection de l'air, de l'eau et du sol ont fixé des normes strictes de qualité de l'environnement pour les industries locales. Dès le début de l'histoire industrielle du site, les valeurs limites d'émission pour toutes les unités de Kemira Oy ont été très basses. Des précautions spécifiques ont été prises dès le stade de conception de l'infrastructure, de la collecte de l'eau, du rejet du gypse sur terre et du développement du procédé.

Les exigences de bas coûts de production impliquent une intégration raisonnée de toutes les unités de production d'un site industriel opérationnel. Le bilan énergétique doit permettre de maîtriser les eaux de procédé et de pluie pour empêcher les rejets dans les lacs et minimiser les traitements chimiques. Les éléments essentiels des techniques d'environnement seront présentés dans cet exposé. Le dernier facteur, mais non le moindre, pour une opération réussie et un avenir viable est la contribution d'un personnel innovateur et actif en charge du contrôle de l'environnement.

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1. DESCRIPTION OF SURROUNDINGS

Kemira began its production activities at Siilinjärvi in 1969.

The production site is located at an inland lake area in Eastern Finland **(Figure 1)**. This far in the north the climate is harsh; for approximately six months each year the area lies under a cover of ice and snow, and the temperature can sometimes stay as low as minus 35 centigrade for extended periods of time. Thus it is vital to understand that the local ecosystem has a very limited capacity to tolerate extra industrial stresses.

2. SELECTION OF THE SITE

2.1. Growing demand for fertilizers in Central and Eastern Finland

Before the establishment of the Siilinjärvi production site Kemira's markets in Central and Eastern Finland were supplied from the production plant in Kotka on the southern coast of Finland and from the Kokkola plant in Ostrobothnia. However, operations in Kotka became gradually increasingly difficult. Transport connections to Central Finland were long and, as the town expanded, the production facilities started to be situated slightly too close to housing areas. Thus from an environmental standpoint, the location of the plant had become unfavourable. Environmental considerations also prohibited the relocation of production to Kokkola. The soil surrounding the Kokkola plant was flat and had a high sand content, thus providing easy permeation to acids, and the construction of the disposal areas for phosphogypsum and the ponds for the closed water loop would have been both difficult and expensive.

2.2. Siilinjärvi as an industrial location

The Siilinjärvi site is located in Northern Savo province about 30 kilometres to the north from the administrative centre of the province, Kuopio. In addition to the many advantages offered by the area for the establishment of a production facility, some considerable challenges were also present. The site is located in the middle of Kemira's market area, and in addition to good road and railway connections the Siilinjärvi municipality also operates a landing field for airplanes. The supply of raw materials presented no problems. A railway line to the east runs through the site, and a new copper mine had just been founded along the line which enabled the Siilinjärvi facility to utilise the sulphite ore - a mining by-product - from the mine as raw material for the production of sulphuric acid. Another connection provided by the railway line was to the Outokumpu copper mine, where concentrates were also available as raw material for sulphuric acid production. Furthermore, the railway line also provided a link to the eastern border of Finland and continued with the same rail gauge all the way to Soviet plants producing ammonia, Kola phosphate and potassium salt. Since then the transport connection have improved as the port of the Siilinjärvi site has been connected via the Saimaa Canal to the Gulf of Finland and the Baltic.

A deposit of apatite is found a few kilometres from the Siilinjärvi site. When the site was established, the technology for the utilisation of ore had not yet been developed and the price of phosphate was low enough to preclude mining by Kemira. As years went by, however, the situation changed, and now ore has been used successfully for nearly 15 years as raw material for the production of phosphoric acid and fertilizers. Our own rock phosphate has also proved to be suitable for the production of phosphoric acid.

As the demand for fertilizers was growing in Eastern Finland at the time and since all raw materials were readily available, the selection of Siilinjärvi for the site was logistically a very clear choice, as described above.

3. DESCRIPTION OF THE SITE

3.1. Phase 1: 1968 - 1969

The decision to build a "green field" site was made in 1967. Construction started the following year with a roasting plant, a single stream sulphuric acid plant , a single stream phosphoric acid plant and a single stream monoammonium phosphate plant, together with a power station.

3.2. Phase 2: 1972 - 1973

The second phase included the facilities for the launching of the production of compound fertilizers i.e. a single stream nitric acid plant, a single stream compound fertilizer plant with two granulation loops and the required storage and bagging facilities.

In 1973, the phosphoric acid plant was modified from the hemi-dihydrate process to dihydrate process owing to conversion problems with Kola apatite.

3.3. Phase 3: 1978 - 1979

The next development was to start the mining operations. The decision was made in 1977, following intensive development work by Kemira.

Construction was started in 1978 for open pit mining and a single stream concentration unit.

The monoammonium phosphate plant was already closed in 1977.

3.4. Current situation

The further developments of the site included increasing the capacity of the phosphoric acid plant, and the mine which was completed in 1982. Later on, the utilisation of by-products was improved, including the mining operations and the partial utilisation of phosphogypsum.

The current situation is described in **Figure 2**.

4. ENVIRONMENTAL PROTECTION

4.1. Air pollution control

When the Siilinjärvi site was being planned and under construction, air pollution control legislation had yet to be enacted in Finland. The plants for the site were thus based on the lowest possible level of emissions, designed to minimise environmental damage.

The site is surrounded by low wooded hills with a mainly coniferous tree stock. The distance from the site to the nearest housing area is five kilometres. The total land area owned by Kemira at Siilinjärvi is about 3000 hectares, which provides for an adequate safety zone. Since the prevailing winds are from the south and the site is located to the north of housing areas, smoke emissions are mostly carried to the north towards areas owned by Kemira. The coniferous forests in this climatic zone are particularly sensitive to air impurities, especially fluorides, but also to sulphuric and nitric oxides. The harsh conditions in winter reduce the tolerance of trees to chemical stress. Thus the minimisation of damage to the tree stock has called for a careful limitation of emissions and the close monitoring of their diffusion and effects. One solution to the problem has been to partially adapt nature to the conditions. Safety zones have been established at the boundaries of the site and along the road leading to the site by planting trees with better tolerance for atmospheric pollutants, and birch saplings have been planted to augment other deciduous trees at and near the site.

4.2. Protection of water and soil

When the site was being planned, the plans were based on the then current water law, which required a permission for liquid effluent and also categorically prohibited the pollution of groundwater.

The Siilinjärvi site is characterised by a profusion of lakes in the area. The lakes are part of the extensive Vuoksi system of lakes and waterways which empties into Lake Ladoga in Russia. Although the system of waterways is extensive, the lakes which border the Siilinjärvi site are just small headwaters; their flow rate is relatively small and thus their load-bearing capacity is easily exceeded. Since phosphorus is a minimum nutrient factor in the water system, even a small increase in the phosphorus content induces the growth of algae, and prolonged period of high phosphorus content causes eutrophication. Because the lakes are frozen over for approximately six months every year, eutrophication also causes oxygen depletion in the basins. The waters have a rich and varied stock of fish, the preservation of which is one objective of our measures for water protection.

In order to minimise unfavourable changes in the water system the phosphate load must be maintained at an extremely low level. To achieve this, all effluents and drainage water containing chemicals are either channelled to closed water loop systems or purified chemically before being emptied into the lake system. The undulating terrain facilitates the treatment of drainage water in that it allows the construction of disposal areas and ponds in such manner that the waters flow naturally to the processing systems. A soil-density analysis was done prior to deciding the locations for waste material stores and the pond for recycled water. The analysis revealed that the area abounds in moraine and clay, both of which have very low permeability, thus making it possible to reserve suitable sites for the processing of solid wastes and drainage waters. Since there are no groundwater intakes or private wells in the area, there was no risk that domestic waters would be affected through groundwater. However, since the groundwaters flow gradually into the lake system, the quality of the groundwater and its flow rates have been monitored and corrective measures have been undertaken when necessary.

4.3. Detailed design basis

As described above, the goal was to minimise all emissions and effluents whatsoever. Thus the most environmentally critical operations were:

1. the production of phosphoric acid, including the gypsum pile and the pond area,
2. the production of fertilizers, and
3. mining operations.

Iron oxide from the roasting plant was supplied directly to a Finnish steel mill.

The design basis and the current permitted limits are as follows:

Water: **Effluents**

	Original design	Permit Original	Permit Current	Current level
Site				
N	Nil	-		1)
Lake Kuuslahti				
P, kg/d	Nil	8	3	1
BOD, mg/l		5	5	
Solids, mg/l		30	15	
Lake Sulkava				
P, kg/d	Nil	2	2	< 0,5

1) Target to reduce to the level of 30 kg NH_4^+-N/d

Air: Original design basis

The original design was goal to keep emissions as low as possible, the crucial factor being:
- no damages to the environment
- the existing technology.

Revisions

1	1975	F	Modification of the gas scrubbing at the monoammonium phosphate plant.
2	1982	SO_2	Sulphuric acid plant 2 due to the double contact (DC) process
3	1984	F	Closed loop of the cooling on the phosphoric acid plant.
4	1985	NH_4-N NO_3-N F	Compound fertilizer plant due to improved scrubbing technology
5	1988	SO_2	Sulphuric acid plant 1 was revamped including DC
6	1988	Dust	Concentration plant on the mine
7	1990	NO_x	NO_x abatement on the nitric acid plant
8	1991	F	Modification of the gas scrubbing and droplet separation in the phosphoric acid plant

The reasons for these modifications were:

- Occasional minor damages visible in the nearby environment
- New legislation
- Trends in international regulations and treaties

4.4. Permits

Current environmental legislation in Finland is fairly extensive, and the limits set down by the authorities are tight on an international scale. Especially the control of water pollution has been an object of constant concern for both the authorities and private citizens, since the numerous lakes are considered a typical characteristic of the country and are a source of national pride.

One characteristic of the Finnish permit system it that it provides for the broad, public and democratic participation in the permit process for those who may possibly have to suffer from the emissions. Another special feature is that permits are granted on a case basis. Instead of being based solely on national or industrial norms, the permit takes into account not only legislation, but also the views of the inhabitants of the area in question, the available technology, and the tolerance of nature. Thus, for instance, different fertilizer plants have different permit limits in Finland. The permits are often granted for a limited period of time to enable later revision due to developments in requirements, knowledge and technology. Significant changes in production processes as well as extensions of plant facilities necessitate the application of a new permit. Operators are required to report to the authorities the results of all surveys and loads to the environment, and also any situations which may have caused deviation from the limits as well as measures undertaken to correct the situation. The authorities are empowered to inspect facilities and take samples. In order to ensure that the permits are reasonable and fair, it is extremely important to maintain an active cooperation and dialogue with the authorities and other interest groups, especially during the application process before the final decisions are made.

4.5. Social factors in the Siilinjärvi area

Siilinjärvi is mainly an agricultural area where the inhabitants are not used to the presence of industry. Consequently their attitude towards industrial activity is one of mistrust and apprehension. This attitude is fostered by the media, which focus their coverage much too often on the disadvantages of industry.

However, the municipal authorities in Siilinjärvi very quickly realised the boons of the site to the municipality and its welfare, taking a very positive, cooperative attitude right from the start. Negotiations for the purchase of the land areas required by the facility were carried out by the municipality, which then sold the areas it had acquired to Kemira. The municipality has also taken part in the negotiations for the purchase of additional areas to ensure that the price of land is determined fairly for all farmers.

Many of the studies concerning environmental effects have been carried out in cooperation with the municipal environmental authorities and local industrial operators. Examples of this include a joint follow-up study of the waters in the area made together with the municipal authorities; studies of air quality done in cooperation with both the municipality and industrial operators; and a bio indicator investigation into the status of the forests in the area. The pooling of resources enabled sharing of costs, and the studies became geographically much broader.

Fruitful cooperation has also taken place with the different associations and societies in the area. Questions concerning the management of fish stock and matters of compensation have been solved in cooperation with the owners of the water areas and the local fishing associations, whereas forest surveys have been planned and followed through by a group consisting of representatives from research institutes, municipal administration and the local forestry society.

Also the schools in Siilinjärvi have proved to be a significant partner in cooperation. We have introduced both teachers and pupils to the working of the site in order to replace the mistrust felt by youngsters with facts, and thus to ensure the supply of motivated employees also in the future.

There is relatively little nature activism in Siilinjärvi. Although the majority of the population takes today a positive attitude towards our activities, there are still some farmers in the area who are concerned over the nature in their home district and who, during the permit application process, come up with criticism and demands which cannot but seem unreasonable to us. They also possess the ability to present their demands in a highly visibly manner through the media.

5. COMPARISON OF SIILINJÄRVI OPERATIONS VS. BAT

Criteria for the best available techniques (BAT) are still under preparation. According to the proposals available thus far, the situation at the Siilinjärvi site is as follows:

	Permit	Actual	BAT
Sulphuric acid plant (DC)			
Total kg SO_2/t prod.	4	1,29	2
Nitric acid plant			
NO_2 kg N/t N prod.	1,96	1,16	1,72
NO_2 ppm	186 (200 t NO_2/a)	146	200
Phosphoric acid plant			
F kg/t P_2O_5	0,063	0,050	0,040 [1]
P kg/t P_2O_5	0,008	0,003	8,7 [2]
Fertilizer plant			
NH_3 kg/t prod.	0,54	0,10	0,2
NO_3-N kg/t prod.	0,11	0,04	-
NO_2 kg/t prod.	no limit	[3]	0,7
F kg/t prod.	0,0022	0,0022	0,02
Total kg N/t N prod.	no limit	0,63	2,66
Site			
Total kg N/t N prod.		1,63	

[1] Only the reaction section.
[2] In case gypsum is discharged into water.
[3] Included into NO_3-N emission.

The conclusion is that the site is already at present (and also has been) far below the proposed BAT values.

6. PERFORMANCE

Even if the design criteria have been very strict, some modifications have been made due to:

- improvements in available technology
- dome minor damages visible in the trees near the factory
- the tightening of permit values by the authorities

However, each time when the production capacity has been increased, it has been done within the existing permit limits.

The performance of the site is illustrated in **Figures 3 - 7**.

7. MONITORING AND RISK MANAGEMENT

7.1. Selecting purification technology

In order to comply with the emission limits set by the authorities, the selection of a sufficiently effective technology is of the utmost importance. In fact we have succeeded so well in our choice of purification technologies that we are able to fall below the permitted limits in all areas of our operations.

The successful selection of techniques is not, however, sufficient guarantee against breaches of limits or discharges due to malfunction. Thus, to comply with the requirements, we have developed techniques for monitoring significant emissions, and personnel has been encouraged to actively observe and prevent all damaging effects to the nature in their own home area.

7.2. Monitoring the amount of nutrients in water

The quality of the liquid effluents from the site to the surrounding waters is continuously monitored from the control rooms. The outlets of the cooling water system are equiped with on-line conductivity measurements, which enable us to pinpoint the location of possible leaks immediately at all times, and preventive action can be undertaken without delay. The drainage and sanitary waters produced at the site are accumulated in a chemical purification plant, where precipitation is automatically controlled and operational conditions are constantly monitored from the control room at the nearby sulphuric acid plant. In addition effluent ducts have on-line sampling and flow rate measuring devices. The amount of nutrients in the effluents is determined daily with analyses and flow rate data.

In accordance with current legislation and our effluent permit, we are also required to perform a risk analysis.

In our case the most critical risks are:

- very heavy rainfall [>100 mm within the space of a few hours (in average 700 mm/a)]
- severe damage to:
    - phosphoric acid tanks which in our case are drained to the pond area
    - NH_3 tank (a sphere 1000 t and an athospheric tank 5000 t)

7.3. Monitoring of atmospheric loads

The stacks of the sulphuric acid, nitric acid and phosphoric acid plants are fitted with on-line analyser which provide continuous monitoring for emissions of SO_2, NO_2 and HF. As the control rooms also receive a constant flow of data from the numerous other parameters of gas purification, we have achieved the desired level in the control of emissions.

However, some of the required measurements are so demanding that no commercial solutions have been available for their performance. For example, the waste gas from the fertilizer plant is saturated with steam and it contains several gaseous and particulate components. In order to be able to monitor this particular emission we have developed an on-line sampling device, with the samples being analysed three times a week. In addition there are other continuous measurements which enable us to monitor changes in the level of emissions. Information from the samples and flow rate data are used to calculate emissions of nitrogen (NH_4-N, NO_3-N) and fluor (HF) both emissions subject to permission.

In addition to gaseous emissions from the stacks, the permit limit for the phosphoric acid plant includes also the evaporation of fluorides from the gypsum pile and from the ponds for recycled water. In order to measure these emissions we have developed a mathematical model which calculates atmospheric loads on the basis of imbedded emission-related measurement data and weather information.

The emission from the phosphorous acid plant are monitored in accordance with the BS7750.

7.4. The emission of chemicals to the surroundings

We also actively monitor the emission of chemicals to the surroundings and their effects in nature. The water body used to receive the emissions has nearly 20 observation points in the basins and at points of discharge. Samples taken quarterly are used to monitor the chemical and physical properties of the water. In summer biological production capacity is monitored, and once every three years a comprehensive ecological survey is made of the status of the fish stock, benthic animals and aquatic vegetation. The water authorities use the data from these studies in defining the permit limits.

In terms of nature, the most significant evaporating chemicals is fluor, the diffusion and effects of which are monitored with extra care. The annual, monthly and daily averages of fluor concentrations in the air are determined with the aid of emission data, weather data and knowledge of the geography of the area. The results are then compared with norms for the quality of air. In addition we monitor the accumulation of fluor in the soil, as well as in the hay used as fodder for grazing livestock. The status of the forests is monitored using bio indicator studies. These studies include e.g. classification of the health of the tree stock and of lichen, as well as measurement of the sulphur and fluor content in needles.

8. SUMMARY

Since the very beginning, one of the most important design criteria for the Siilinjärvi site has been to maintain the liquid effluent and emission levels as low as possible.

In environmental terms, the selected strategy has proved to be the correct one. With 25 years of experience in operating the site, we can conclude that:

- the site has not produced any significant changes in the environment, and
- all the individual plants meet the proposed values for BAT.

If we compare the performance of the site with other areal emittors with respect to N, P and BOD, we are far at the top, especially in the case of P and BOD emissions. In order to be able to maintain this outstanding performance, it is necessary that all the various activities (i.e. design and planning, implementation, operations, monitoring and reporting) are properly organised from the environmental standpoint. This means that even if we are not yet officially complying with any national or international codes, we are in fact applying them where appropriate, the BS7750 code being a case in point.

The advantage of this policy is that we have everything organised, while not being committed to any one code. However, the system can be audited at any time without any problems.

As a final conclusion, we are convinced that this kind of fertilizer complex is a very competitive option when new production sites are being considered. However, environmental damages cannot be prevented unless local conditions are taken into consideration.

There is one more point which merits emphasising in the case outlined above. The phosphoric acid plant and all the related facilities have an annual production capacity equivalent to approximately three million tons of compound fertilizers. Nevertheless, a mere ten percent or so of the phosphoric acid produced is used for further processing at the Siilinjärvi site. The rest of the acid is transported to other locations in Finland or abroad to be used as raw material for fertilizers or other kinds of technical products.

Figure 1 **Kemira Worldwide Production Plants**

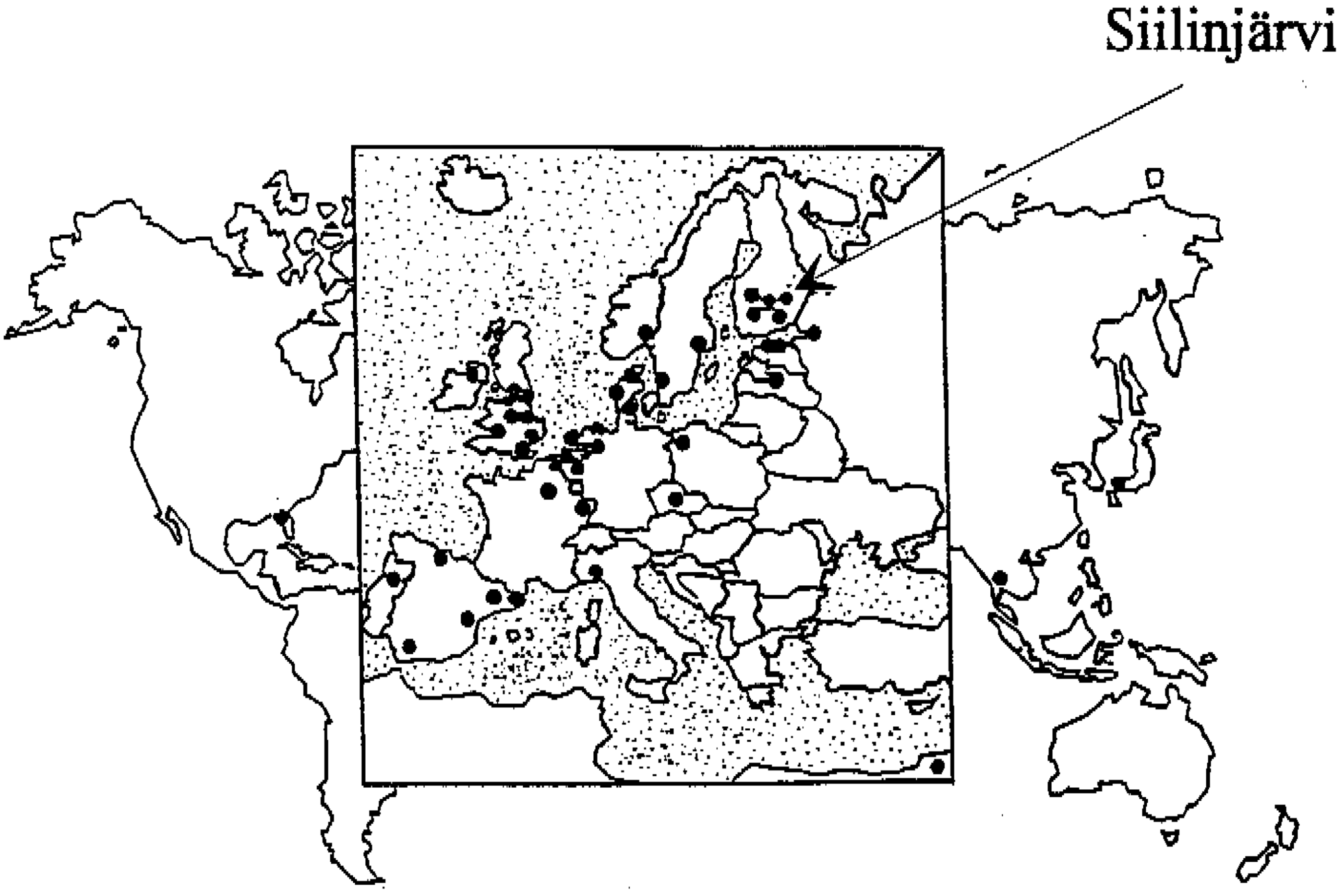


Figure 2 **Siilinjärvi Mine and Chemical Plants**

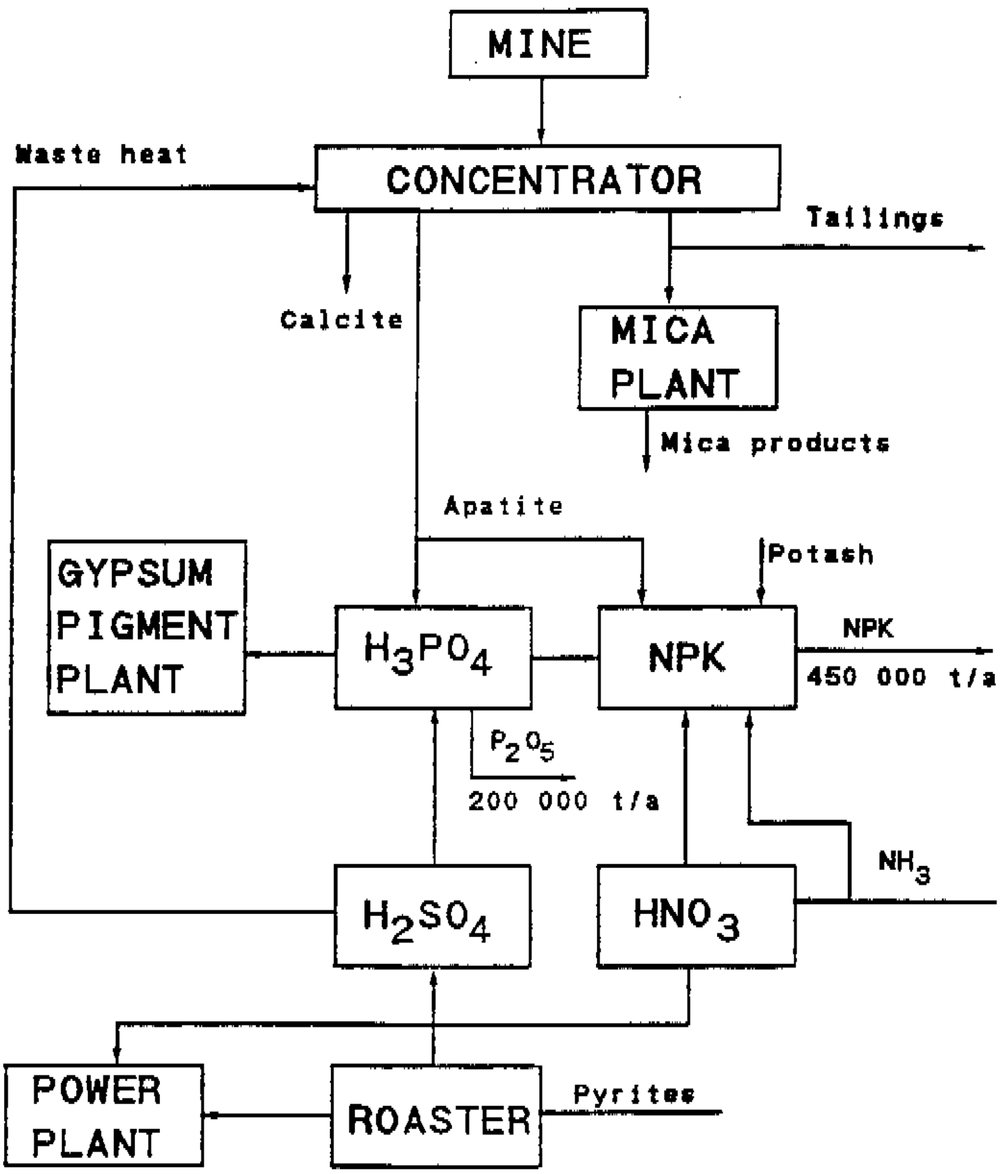
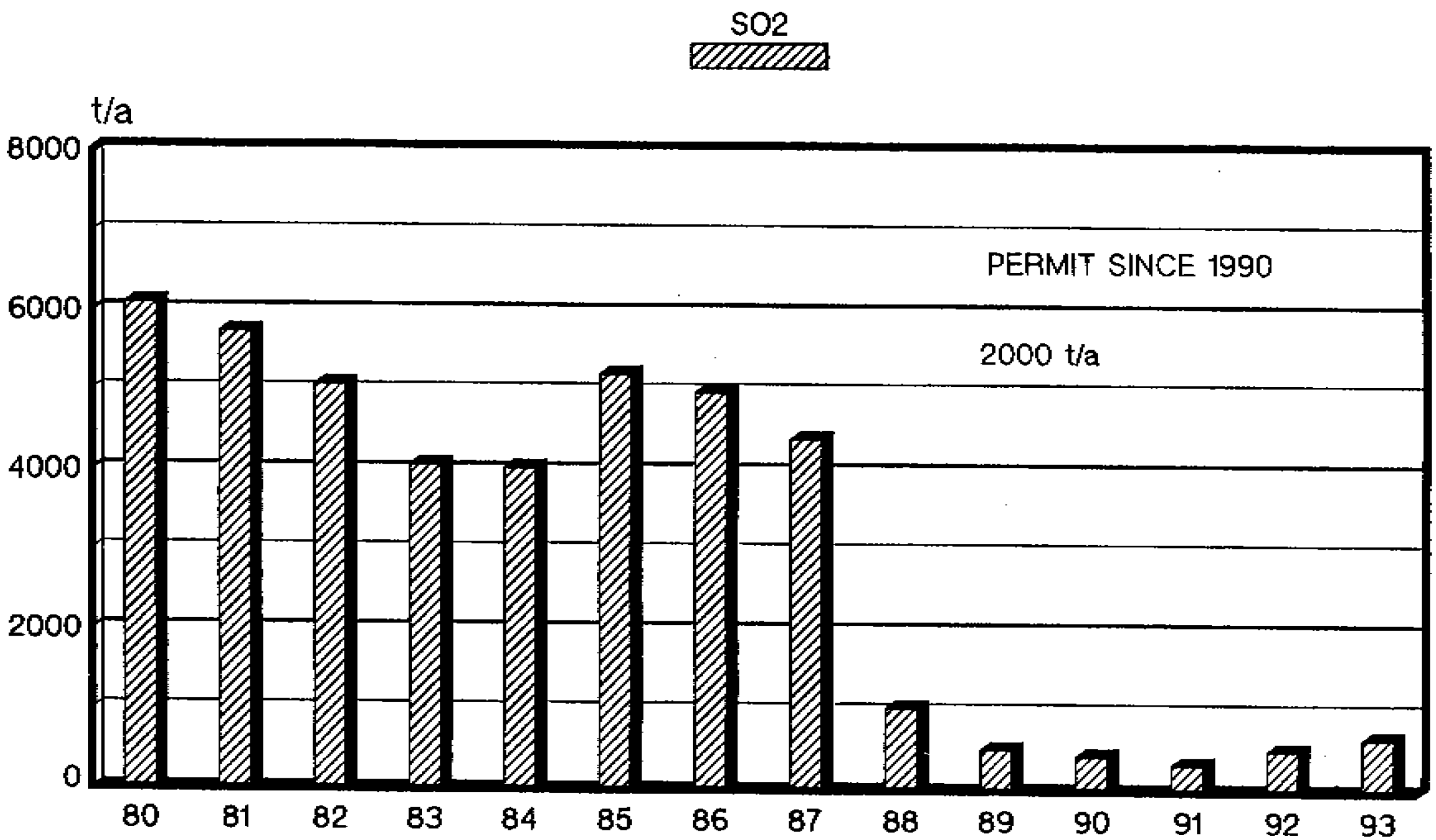


Figure 3 SULPHUR DIOXIDE EMISSIONS



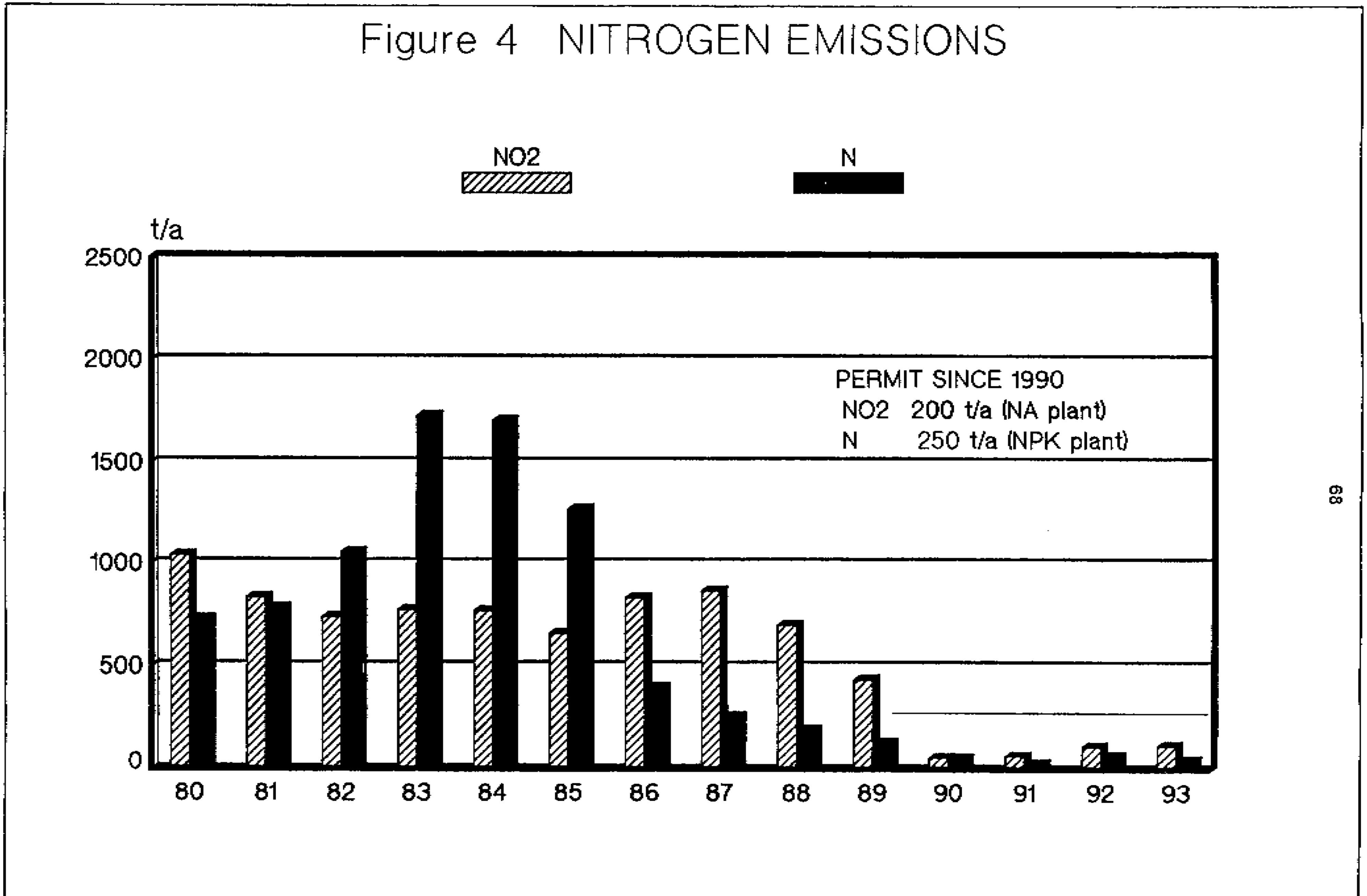


Figure 4 NITROGEN EMISSIONS
NO2
N
t/a
2500
2000
1500
1000
500
0
PERMIT SINCE 1990
NO2 200 t/a (NA plant)
N 250 t/a (NPK plant)
80
81
82
83
84
85
86
87
88
89
90
91
92
93

Figure 5 PHOSPHOROUS EFFLUENTS

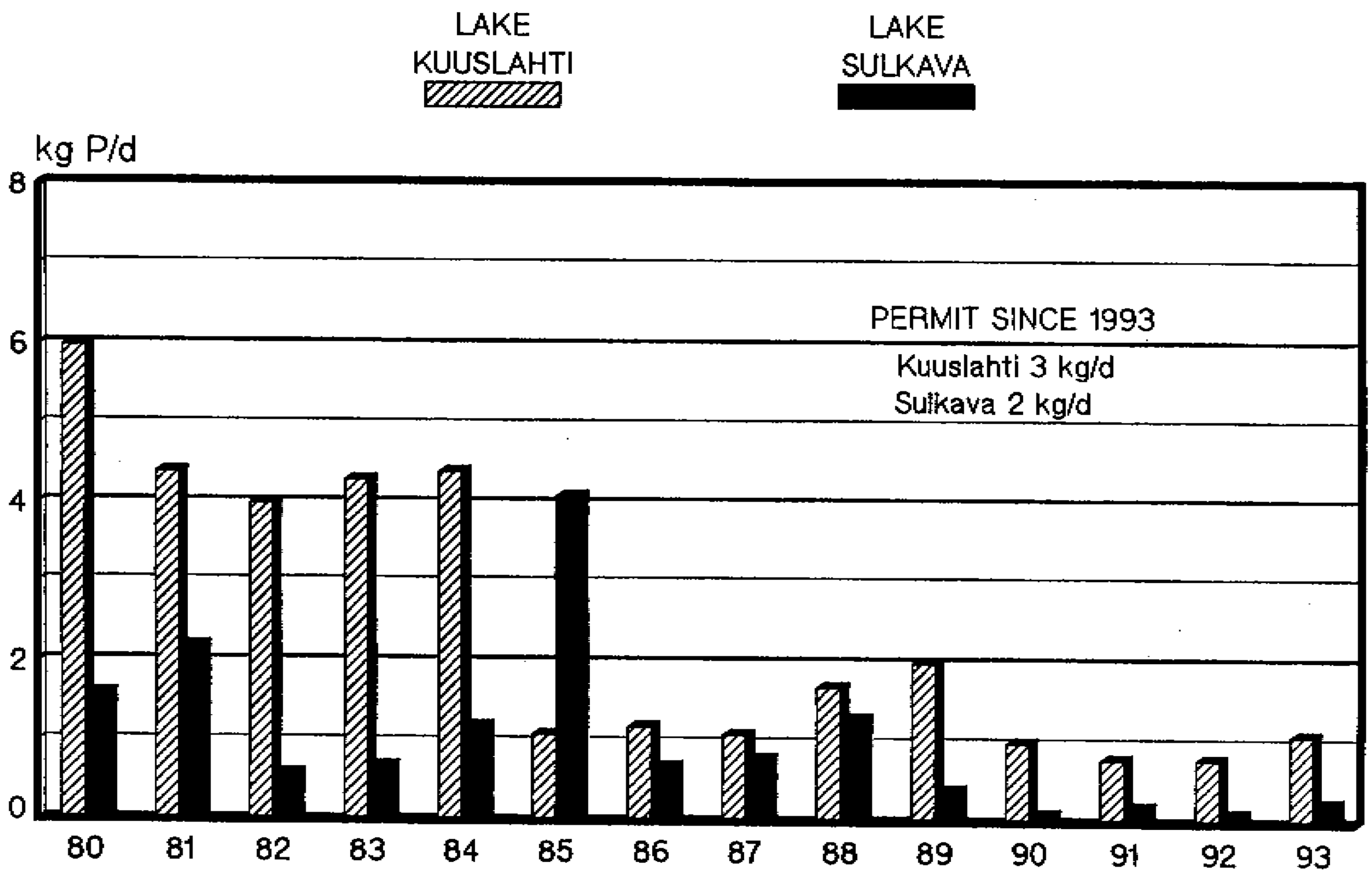


Figure 6 FLUOR EMISSIONS

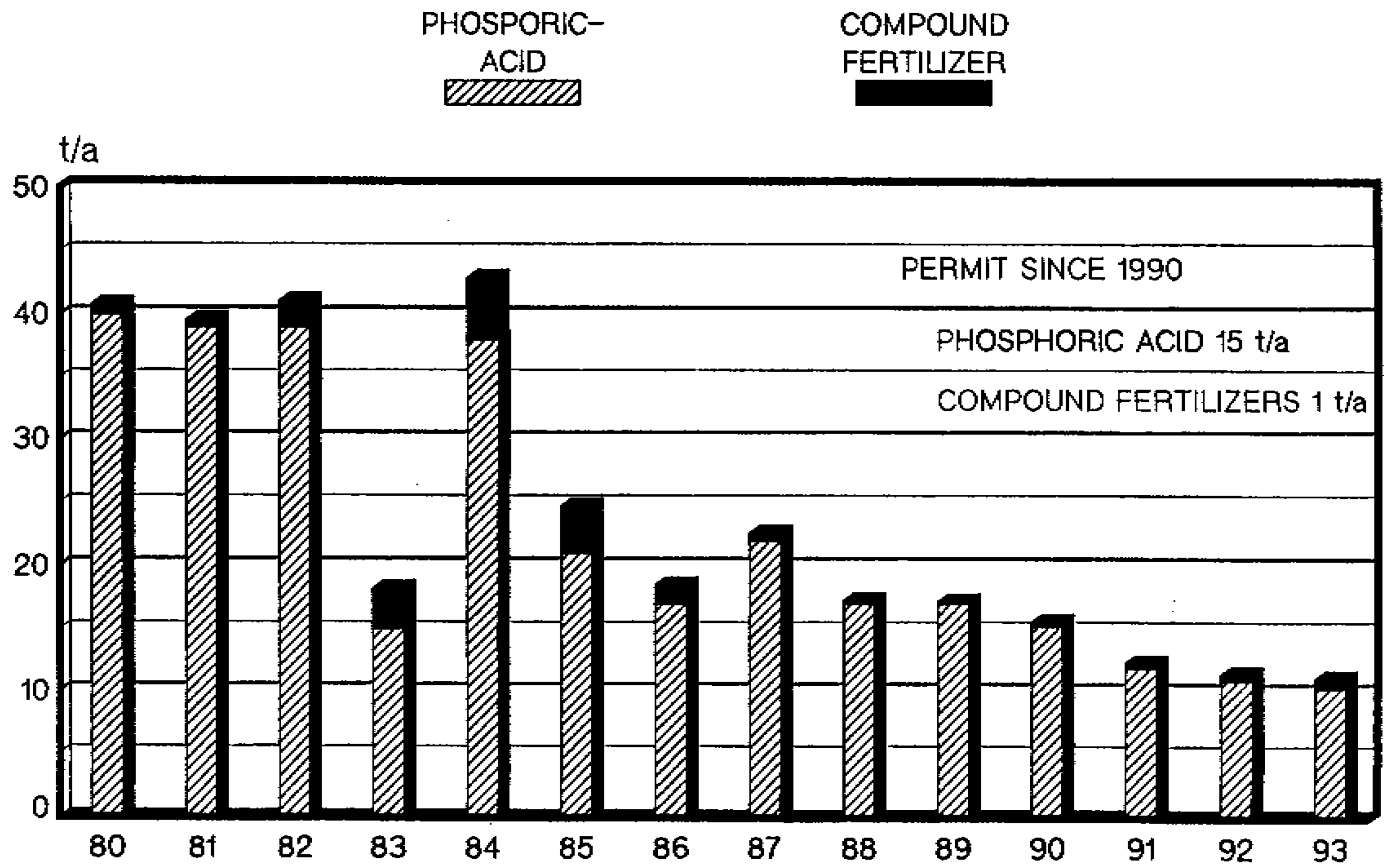


Figure 7 NITROGEN EFFLUENTS