Part Three

PREVENTION AND CONTROL OF WATER POLLUTION FROM FERTILIZERS AND PESTICIDES

INTRODUCTION

The introduction in a number of UN/ECE countries of new legislation to control and reduce water pollution from point sources was aimed at achieving stricter measures for pollution prevention at source, as well as the implementation of add-on measures such as advanced sewage treatment. In countries where such legislation has been introduced, both the relative and the absolute contribution of emissions of nutrients from point sources to the total load of inland waters has decreased. Although in these countries the formulation of measures to prevent, control and reduce water pollution from non-point sources, in particular those in agriculture, has received as much attention, perceptible results in the process of implementation have not always been achieved on a large scale. The reasons for the still unchanged large-scale impact of agriculture on water resources are manifold.

It is only in recent years that the concept of sustainable agriculture has brought about substantial changes in agrarian policy and structural changes in some countries. These have promoted, *inter alia,* a better integration of sectoral agricultural developments into the environmental policy. However, although strategies have been developed for the environmentally sound use of fertilizers and pesticides, there are still areas where methods for further reducing their use should be developed and implemented.

As a reflection of the increasing concern over the extent of the problem both at the national and international levels, the prevention and control of water pollution from fertilizers and pesticides released from agricultural sources has become one of the goals of the UN/ECE *Regional Strategy for Environmental Protection and Rational Use of Natural Resources* (ECE/ENVWA/5). The UN/ECE *Charter on Ground-water Management* (ECE/ENVWA/12), the Recommendations on the *Protection of Soil and Aquifers against Non-point Source Pollution* (WATER/SEM.14/3. as amended in ECE/ ENVWA/3), *Waste-water Management (ENVWAI* SEM.4/3), and the *Protection of Inland Waters against Eutrophication* (ECE/ENVWA/26) represent a collective response of UN/ECE Governments for the attainment of this goal.

The prevention, control and reduction of the transboundary impact of water pollution from agricultural sources is an objective of the *Convention on the Protection and Use of Transboundary Watercourses and International Lakes.* According to that Convention, the Parties shall develop, adopt, implement and, as far as possible, render compatible relevant legal, administrative, economic, financial and technical measures, in order to ensure, *inter alia,* that appropriate measures and best environmental practices are developed and implemented to reduce inputs of nutrients and hazardous substances from diffuse sources, especially where the main sources are agricultural. Furthermore, the Convention provides for the total or partial prohibition of the production or use of hazardous substances (article 3, paragraph 2). The Convention also obliges the Parties bordering the same transboundary waters to develop concerted action programmes for the reduction of pollution loads from point and diffuse sources (particularly in agriculture) in the catchment area of the transboundary waters or part(s) thereof, subject to cooperation (article 9, paragraph 2 (f)).

Taking these considerations into account, this part of the publication examines national and international experience gained in coping effectively with the adverse effects of agriculture on inland waters. Due attention is given to the need to maintain viable agricultural production. It also reviews major water pollution problems related to current agricultural practices; analyses the causes of these problems; evaluates legislative measures, regulatory instruments, and economic and technical measures to prevent, control and reduce water pollution from fertilizers and pesticides; and examines accompanying measures in the fields of economic policies, technology, education, training, awareness raising, research, and development.

Particular attention has been given in the preparation of this part to recent documents on water and agriculture issued by other international organizations in the UN/ECE region. These include documents of the Food and Agriculture Organization (FAO); the European Community: the Helsinki, Oslo and Paris Commissions on the protection of the Baltic Sea and the North East Atlantic, respectively; and reports prepared within the framework of the Mediterranean Action Plan. The 1991 EC *Council Directive Concerning the Protection of* Wa-

ters Against Pollution Caused by Nitrates from Agricultural Sources (91/676/EEC)- and the decision of the EC Council of December 1991 concerning the outcome of the *Ministerial Seminar on Groundwater* held at The Hague (4373/92/ENV15) were taken into account in particular.

I. CURRENT SITUATION

A. Water pollution from agricultural practices

During the past four decades, agriculture has undergone a structural change in many UN/ECE countries. These changes are characterized by economies of scale, mechanization, intensification and specialization. Intensive farming relies in many cases not only on the extensive use of fertilizers and pesticides, but also on irrigation or sprinkling, mechanization and improved plant varieties. Some of these practices, such as the extensive use of fertilizers and pesticides, irrigation and the use of heavy machinery, have or may have adverse effects on water and soil.

In a number of countries, the area of agricultural land has decreased. A general reduction in total agricultural area was related to a shift in arable and permanent cropland, on the one hand, and to permanent grassland, on the other. Cropland has, for the most part, increased at the expense of permanent grassland. In almost all eastern European countries, farm size has been extended.

Agricultural production has increased in many UN/ECE countries. Crop production has become more specialized. Animal husbandry has been expanded and concentrated in specialized farms and particular areas of a country. A major factor in intensive livestock farming is the production of large amounts of animal manure.

Nitrogenous fertilizer use grew in most UN/ECE countries, and stabilized in some countries in the late 1980s. Phosphate consumption was much lower and much less variable than the consumption of nitrogenous fertilizer. Rates of application of pesticides vary considerably between UN/ECE countries. The UN/ECE publication *The Environment in Europe and North America* (Statistical Standards and Studies, No. 42, New York, 1992) contains most recent data on the use of fertilizers and pesticides.

The extensive use of fertilizers and pesticides has a considerable impact on the environment in general and on water resources in particular. Water is also a medium by which adverse effects resulting from agricultural activities are transmitted to other environmental media.

Most noticeable is the contamination of water by nitrogen and phosphorus compounds, oxidizable organic matter and pesticides. This has, *inter alia,* led to the eutrophication of surface waters and marine ecosystems by nutrients either directly introduced into these waters or indirectly introduced via the interconnection of groundwater and surface waters. Emissions of oxidizable matter and pesticides have led to fish kills and other adverse impacts on aquatic life. Soil compaction and soil erosion as well as air pollution, produced by certain agricultural practices, have also directly or indirectly affected the quality of water in the unsaturated zone and/or the quality of surface water and groundwater.

Drainage systems may also have adverse impacts on water quality. These systems limit the recharge of the water table and increase the removal of surface water from agricultural land. Higher water fluxes may deliver high amounts of matter which are transported into surface water and groundwater.

Agriculture, in particular, is a major source of nitrate pollution of inland waters. The amount of nitrate leaching depends on a number of factors, such as the quantity and type of fertilizer applied, the type of crop, the soil type and the time of the fertilizer application. Increased concentration of nitrogen was even observed in deep groundwater, for example, in parts of Belgium, France, Germany, the Netherlands and the United Kingdom. Over a long period, the ecological functions of such aquifers are adversely affected if not damaged, and they will be less acceptable as a source of drinking water.

In general, phosphates are almost entirely absorbed into the topsoil. Depending on site conditions, the percentage of water pollution caused by erosion may be very high with regard to the input of phosphates. On sites where there is intensive fertilization and low absorptive soil capacity, phosphates can leach into the groundwater and surface water. This may occur especially in areas with many intensive livestock farms, where there is a limited area available for the application of large amounts of manure. Such intense application has led to water pollution and the eutrophication of inland waters, including the excessive growth of algae and higher water plants therein, as analysed, for example, in the UN/ECE report on *Protection of Inland Waters against Eutrophication* (ECE/ENVWA/26).

Already the average amounts of mineral fertilizers applied in a given country is an indication of a danger potential. However, considerable water loads may also occur in countries that report low overall use of fertilizers if their application is very unevenly distributed throughout the country. This can result in high nutrient loads in soils and inland water locally and can also contribute to increasing nutrient loading of coastal waters in the region.

The intensive use of pesticides in present crop protection methods has also produced some undesirable side-effects. These include, *inter alia,* pollution of groundwater; contamination of precipitation and pollution of surface waters, sometimes resulting in harmful effects on non-target aquatic organisms; and deterioration of aquatic and terrestrial ecosystems by diminishing the original variety of flora and fauna or bio-accumulation in the food web. Problems such as resistant plague organisms, the need to increase the dosage due to the rapid degradation of the applied pesticide by adapted soil microorganisms, and the high cost of pesticides for low-profit crops have become evident.

In spite of a certain degree of degradation and dilution of pesticides in the soil, there is a risk of an increase in pesticides leached from the soil and subsequently transported to shallow and deep aquifers and/or surface waters. Depending on site conditions, the percentage of water pollution caused by erosion may also be considerable with regard to the input of pesticides. Certain pesticides or their degradation products (pesticide residues or

[2] This directive is hereafter referred to as the EC Nitrate Directive.

specific metabolites) are present in groundwater or surface waters at concentration exceeding those set for drinking water or those adversely affecting aquatic life. Present knowledge about the level of environmental contamination or the ecological effects of pesticides is, however, limited. Chemical analysis of pesticides is complicated, expensive and often not even possible at relevant detection levels. In practice, therefore, only relatively few are examined.

B. Pollution sources

1. *Mineral fertilizers and livestock manure*

In general, excessive fertilizer and slurry rates are considered to be the main sources of water pollution from agriculture. However, more detailed consideration needs to be given to the causal relationships between factors governing the transport of nutrients to water bodies in order to arrive at recommendable action. Nutrient leaching, for example, is influenced by a number of major factors, such as:

(a) Vegetation (leaching from agricultural areas is as follows: leaching from unfertilized permanent grassland < leaching from areas with ley farming, lucerns and clover < leaching from fields with cereals < leaching from potato fields < leaching from fields with beet < leaching from fields with vegetables);

(h) Soil (type, permeability, water storage capacity, organic matter);

(c) The soil's nitrogen mobilization and storage capacity;

(d) The soil's nutrient content or supply (e.g., rate, type and time of fertilization; application technology);

(e) Climatic and meteorological conditions;

(f) Atmospheric inputs;

(g) Cultivation and ploughing (as aeration of the soil stimulates mineralization and nitrification and decreases denitrification);

(h) Crop rotation;

(i) Green cover in autumn and winter (as catch crops and as a means of decreasing erosion).

In addition to the direct introduction of liquid and semi-liquid manure into water bodies due to carelessness or non-compliance with water legislation (such as manure application on drained or frozen lands as well as close to watercourses), nutrient loading of water bodies partly results from nutrient supplies not meeting the plants' real nutrient demand (e.g., excessive manure rates, bad timing, disregard for the nutrient content or supply, nitrogen mobilization capacity).

The sharp increase in the number of intensive husbandry farms in certain areas in Belgium. Denmark, France, Germany, the Netherlands, the United Kingdom and the United States, for instance, has had a considerable impact on the environment, especially on water resources.

Experience suggests that there are several ways in which intensive livestock production units may pollute the environment. The effects of intensive animal production on ecosystems include ammonia emissions, which are toxic to neighbouring vegetation, including conifers. Specific problems arise from the storage and spreading of effluents, either by emission of acidic gases into the air or by run-off and leaching of manure components into the soil and the waters.

Soil contamination by heavy metals, chiefly copper and zinc, which occur in animal feed and subsequently in manure, has also been observed. Other heavy metals, such as cadmium, which are common in sewage sludge and some mineral fertilizers, have increased the heavy metal concentration in the top soil due to the use of contaminated sewage sludge and fertilizers. Any adverse influence that these metals have depends not only on their quantity in the soil but, above all, on their concentration in the soil water. The effect of soil characteristics (e.g., pH, organic matter content) is paramount in this respect. The more acid a soil, the less it retains heavy metals. Metals enter the liquid phase and become more readily available for plant uptake. This creates a hazard as they enter into the food web.

Many of the above pollution sources have been made worse by the growth and intensification of animal husbandry in recent years and, above all, by its separation from crop and pasture production. Many farmers purchase a substantial proportion of their feed and often have insufficient land over which to spread the manure produced in a manner which does not cause pollution. There has been a tendency to overuse fertilizers, due in part to a lack of information and to the failure to differentiate between yield and profit. Other farmers find it too expensive to utilize animal manure. Another problem is the inadequacy of manure storage facilities.

2. *Pesticides*

Pesticides protect crops against diseases and plagues and normally also increase yield and the quality of the product. Present intensive agriculture, sometimes even based on monocultures, poses a major risk of diseases and plagues. There is an increasing imbalance in the formerly ecologically sound agro-ecosystems.

Pesticides, especially herbicides, have resulted in considerable labour cost savings. There is a wide variety in the pesticides applied and also in the methods and amounts used. The use of pesticides and the number of pesticide applications have increased in the past decades to the current high levels. It is reported, for example, that in the United States pesticide use has doubled since 1964; and in Denmark, the use of pesticides quintupled from 1950 to 1984.

The amount of pesticides that, uncontrolled, ends up in the environment is not known. This may be a question of definition: since pesticides are deliberately applied on the fields one can hardly say that this, in fact, is uncontrolled release. However, the part that is not effectively reaching the targeted plague organisms or crops is unintentionally lost in the environment.

In Germany, Norway, Sweden and the United States and some other countries, pesticide residues have been found in samples of groundwater and surface water in quantities exceeding drinking-water standards and/or ecologically based water-quality criteria and objectives.

Even in samples of rainwater collected at remote stations, pesticide residues have been found.

In the Netherlands, a very rough assessment made for policy purposes is that between two and four per cent of the total amount of pesticides used eventually ends up in groundwater and surface water. This is only an indicative range, since it depends largely on the physico-chemical characteristics of the pesticide involved, as well as on the application, weather and soil conditions.

Pesticides can either be mobile or strongly adsorbed in the organic matter of the soil. They can be volatile, persistent or rapidly degradable by biological or physico-chemical processes such as hydrolysis and photolysis. Sandy soils have only limited binding capacity and, therefore, pose a greater risk of leaching, as in the case of drained fields.

The application of pesticides from aircraft or with strong air blowers, for example, in orchards, tends to have a greater spraying drift than normal field applications. Normally, the drift deposition, expressed as a percentage of the application rate, decreases exponentially with the increase in distance from the treated field. The amount of pesticide that is dispersed in this way depends on the droplet size; the actual wind velocity; the distance between the nozzles of the application equipment and the crops; and the distance between the adjacent water body and the treated field. This implies that the treatment of fields bordering surface waters such as ponds and field ditches, or the maintenance of ditch banks, causes a high rate of pesticide input into these waters.

Granules or fumigants injected into the soil do not produce this kind of drift problem. High wind velocity will cause considerable spray drift to "non-targeted areas". Leaching and run-off (the latter especially on sloping terrain) may occur after intense precipitation also from these non-targeted areas.

In the worst cases, over 10 per cent of the applied amount of pesticides are found in the run-off water (e.g., dissolved in the water or adsorbed in eroded soil particles). This depends on several aspects, such as: the time of application related to the intensity and time of precipitation; the specific degradation and absorption properties of the substance; the condition of the soil (e.g., frozen, compacted) and its water capacity; the slope of the treated area or fields, and the type of crops cultivated.

Regarding the leaching of pesticides, a distinction can be made between leaching into groundwater, sub-surface flow, and flows down preferential pathways. In the case of both preferential and sub-surface flows, the transport to waters occurs in a rather short period of time. In the latter case, this can occur in drained fields, along the field boundaries and sometimes, if there are impervious clay layers present. in the soil profile. The quantity of pesticide that leaches into groundwater or surface waters can be assessed only in general terms because it depends on such variables as:

(a) Specific pesticide properties (mobility, persistence. sorption);

(b) Soil properties (organic content, profile characteristics, presence of macropores);

(c) Drainage network:

(d) Application methods (spraying or injecting in view of crop interception and volatilization) and type of crops;

(e) Soil temperature with respect to degradation;

(f) Weather conditions (e.g.. wet or dry periods, wind characteristics);

(g) Application time (autumn application usually leads to higher leaching rates than spring application).

Many widely-used pesticides, such as bentazone, atrazine, simazine and dinoseb, can be classified as a potentially high risk for leaching into groundwaters. They have also been detected in surface waters. The concentration of pesticides in the shallow groundwater zone is directly related to the amount of pesticide used on the field. The concentration depends on the influencing factors mentioned above, such as sorption and degradation. During transportation to deeper aquifers, dilution with non-polluted water and degradation determine the final concentration. The appearance of pesticides in groundwater is usually a sign that there is more to come, since movement through the soil column may take a long time and be influenced by retardation effects.

A limited number of pesticides are licensed for the control of weeds in water bodies. In general, these substances are approved for use under strict conditions, such as a limited time-period of application or application on dry ditches only. In some countries, for example, in Denmark and Germany, there is already a complete ban on their use for these purposes. Such a ban is also under consideration in the Netherlands.

It was found in the Netherlands that approximately one per cent of the total amount of pesticides used ended up as spray residue or in diluted washings. In general, it can be expected that, from time to time, farmers will want to dispose of pesticide waste. This can happen, for example, when:

(a) An excess of spraying solution was prepared;

(b) Spillage during filling spraying equipment occurred;

(c) Empty pesticides packages and empty pesticide containers remain;

(d) Waste water used in cleaning spraying equipment is to be handled;

(e) Residual solution from immersion baths or sheep dips are to be handled;

(f) Waste water from cleaning agricultural products is to be handled (e.g., some vegetables are cleaned at the farm before despatch).

Furthermore, farmers may need to dispose of leftover pesticides which have passed their shelf-life date. Disposal of waste may also be necessary in cases where leakage has occurred in pesticide stores.

Special attention is required for the cultivation of vegetables and flowers in greenhouses. This will most probably be a specific local problem. Due to intensive irrigation, the risk of leaching is potentially somewhat higher compared to field conditions. There are a number of additional pathways from greenhouses by which pesticides may reach surface waters. These are:

(a) Discharges from condensation -or rain gutters (e.g., deposits of pesticides on the interior glazing of the greenhouse, during application, may run off with condensed water or seep into the exterior rain gutter);

(h) Discharges from overhead irrigation when used for applying pesticides;

(c) Residual water from disposed rockwool mats used as an artificial root medium;

(d) Washing water from the exterior and interior glazing of the greenhouse;

(e) Residual water from special flower treatment.

Apart from the different emission characters, it is especially the very high local concentration of this type of horticulture which causes major water-quality problems.

II. TECHNICAL CONTROL MEASURES

A. Agricultural practices

On a sustainable basis, considering both the economic and ecological points of view, the negative effects of agriculture on water can be effectively prevented, controlled and reduced only at source. For this, it is necessary to find a reasonable combination of yield and water protection requirements.

Therefore, good agricultural practice regarding the nutrient supply of the plants should be orientated, in general, towards the following objectives:

(a) The type, amount and time of fertilizer and manure application should cover the plant's nutrient demand, taking into consideration the nutrients available in the soil and in organic matter. This information may be obtained, for example, from soil and plant analyses or calculations based on regular plot-dedicated records, the conditions of the plot and the kind of cultivation.

(h) Care should be taken to maintain the humus content of soil and adequate lime supply.

(c) Fertilizers and manure should be applied properly by using functionally appropriate technology.

Similar principles have to be applied for:

(a) Land-use management, including crop rotation systems and the proportion of the land area devoted to permanent crops relative to annual tillage crops;

(b) The maintenance of a minimum quantity of vegetation cover during rainy periods to protect the soil from erosion and reduce leaching of nitrates;

(c) The establishment of fertilizer plans on a farm-by-farm basis, and the keeping of records on fertilizer use;

(d) The prevention of water pollution from run-off and the downward water movement beyond the reach of crop roots in irrigation systems.

Several UN/ECE countries have already established codes of good agricultural practice. These codes, which may cover land utilization measures in terms of field patterns, cropping and crop rotation schedules, soil cultivation, sprinkling, and integrated plant protection, are usually applied to the whole country. There is now atendency for these codes also to reflect aspects of protection of water resources.

1. *Prevention of erosion and sit/face run-off*

The prevention of erosion and surface run-off in agricultural areas requires two categories of technical measures, aimed at improving soil characteristics to reduce soil weakness or at better controlling the non-point run-off conditions with the collection of water into streamflows.

The improvement of soil characteristics depends on farming practices aimed at:

(a) Increasing soil resistance against erosion, by maintaining or restoring the physical structure of soils. As the organic complex is a basic factor of soil structure, good farming practices allow for adequate inputs of organic fertilization, at least by digging in crop residues and by green manure intercropping.

(b) Preventing the mechanical destruction of the soil structure as a result of soil compaction by the tyres or caterpillars of heavy tractors, and of the breaking away of the soil aggregates into light particles caused by inappropriate tillage techniques. Against the compaction, especially in the case of a high proportion of silt and clay in heavy soils, the pressure of tractors on the soil can be limited by the use of adapted wheels, tyres or caterpillars, which increase the contact surface, and by using less powerful and slower tractors on sensitive soils. To reduce the breaking down of the soil structure into very light particles, the working speed is reduced, and the choice of the tillage equipment takes into consideration the risk of detrimental effects. Consequently, some types of disk tillers and cultivators are not used in case of erosion sensitivity.

Sheet erosion intensity depends mainly on the potential for wearing away light silt particles by non-point run-off waters. Related to the flow speed, this intensity is a function of the slope and of the distance of flow before collection into streamflows. Ploughing and tillage rows determine preferential flow conditions, accelerate the erosion process if orientated along the steepest slope lines that have, depending on soil characteristics, at least an incline of one to two per cent.

One remedial measure against non-point run-off is the orientation of ploughing and tillage rows along the contour lines, or, if this cannot be done, by accepting a small gradient. This practice can be completed by limiting the length of the rows or by a specific land-use practice of the slope. In the case of steep slopes, especially concave slopes, the most appropriate land-use is permanent grassland. Special attention is needed if steep slopes are used for annual crops. Measures to reduce run-off should be considered, including setting up grassland strips along the contour lines, combined with smooth benches, if appropriate, or by hedges. In any case, bare land is to be avoided during seasons of heavy rains or thunderstorms, either by maintaining a cover of thatch and other crop residues or by intercropping. Usually such practices are planned with due consideration to measures aimed at conserving soil structures.

Such a set of measures does apply to preventing both sheet erosion (by cutting down the non-point run-off) and gully erosion, if combined with appropriate specific techniques for directing the uncontrolled collection of waters into streamflows. For example, when planning a land re-allocation, the outflows are divided into as many small low-speed streamflows as possible by designing field borders and orientating the farm rows according to the land profile and slopes. Stable channels can be designed to collect multiple small streamflows, without damage to their banks, by means of grass strips or plantations.

instances,

In a number of nstances, the choice of the most appropriate remedial or preventive technical measures was subject to risk assessment studies. These were carried out when soil characteristics of large agricultural areas, land profile and slopes had a significant sensitivity to erosion processes. Suitable measures to reduce soil erosion covered, for example, green fallowing, catch crops, winter crops and reduced tillage techniques (e.g., avoidance of mouldboard in autumn). The establishment of sufficiently broad vegetation zones (e.g., filter strips) along watercourses was considered a suitable additional measure.

2. *Reduction of seepage-based inputs*

Many anti-erosion measures that preserve a permanent vegetation cover and conserve or improve the soil pattern are also a means of minimizing seepage-based inputs into water. Intercropping, for example, serves as a means of retaining excessive nitrogen amounts available for the plants and, in the short term, keeping it in the upper soil layer. Preservation of permanent grasslands is aimed at preventing nitrogen mineralization pushes.

It is necessary, however, to carefully check all measures aimed at increasing soil permeability and reducing water storage capacity for their potential to increase leakage-based material inputs into water bodies.

Many measures related to appropriate fertilization can also immediately reduce seepage-based inputs into water. Thus, fertilizer amounts which meet the plants demand and are applied taking into consideration the soil's current supply conditions, further deliveries from the soil reserves and the expected yield level will, in the long term, lead to reduced water pollution loads. The load can be assessed if fertilizer plans on a farm-by-farm basis are established and records are kept on fertilizer use.

3. *Extensification in agriculture*

Up to now, regulatory policy measures for extensification of agrarian production in some UN/ECE countries have been aimed at easing the market and reducing subsidies. At present. the inclusion of environmental considerations into these regulations is under consideration.

There are several extensification measures possible to cover water protection demands, such as: switching from very intensive land utilization to less intensive grassland farming in particular with a view to preventing erosion and reducing seepage-based material outputs; reducing fertilizer and pesticide application; restoring former wetlands and flood plains; simply leaving arable lands fallow: and reforesting. In the last two measures, there is adanger of an initial nitrogen release unless adequate interim measures are taken.

Land set-aside programmes and measures of various types have been discussed and tried in the past with varying degrees of success. Within the European Community, for example, it has now been decided to introduce set-aside as one way of helping to reduce current agricultural problems and the impact of agriculture on the environment.

Practical experience suggests that if farmers were to take crop land out of production for some years, habitat changes with benefits for the terrestrial environment and aquatic ecosystems would occur; but in the case of land set aside for only one or two years, the set-aside could lead to further environmental deterioration under specific conditions, such as extra use of herbicides in connection with weed problems. The ongoing deterioration was particularly severe when the land was left as bare fallow. The same applies to reafforestation without interim measures when the land was exposed to the risk of increased soil erosion or the increased leaching of nutrients.

Although extensification measures are taken in many cases, there is a priority for such measures in water protection areas. However, extensification measures undertaken in water protection areas would be less effective if intensification of agricultural production was under way in other areas.

B. Fertilization

Fertilization, in compliance with water protection requirements, means limiting the application of fertilizers to such an extent that the growing plants can utilize the nutrients from the soil and from mineral and organic fertilizers as completely as possible. According to the 1989 German Fertilizer Act, for instance, it is good agricultural practice for fertilization to be adjusted to the plants and soil according to type, amount and application time, considering the available nutrients and organic substances in the soil and the location and cultivation conditions. The need for nutrient supply to the plant has to be assessed in conformity with yield expectations and the respective local cultivation conditions, and with the quality demands of the products.

The movement of nutrients in cultivated soils depends on the solubility of nutrients. Nitrates are almost exclusively dissolved in the soil water. They are subject to leakage in any condition. Phosphates have a low rate of solubility and are retained by adsorption by silt and clay particles. They are released into the soil water along with the uptake by crops and show a very limited leakage toward the deeper soil layers. Therefore, the risk of pollution depends on their physico-chemical characteristics and the nutrient content of the soils:

(a) Any pollution of groundwater by phosphates will remain very limited, except in the case of some very light sandy soils that allow leakage of undissolved particles. The pollution of surface waters by these components will depend almost exclusively on surface run-off and erosion carrying away soil particles with the adsorbed phosphate molecules. It is therefore necessary to assess the phosphate content of soils in order to estimate

the soil sensitivity to erosion; but this does not require continuous analysis of the sensitivity of soils to erosion if phosphates are correctly applied according to the actual crop requirements.

(h) On the contrary, the great solubility of nitrates is of major importance for their content in the soil water, with the probability of leakage toward groundwater. Therefore, there is a need to continuously assess the nitrate content of the soil water in order to determine the actual fertilization requirement. The nitrate concentration of the soil water able to minimize the leakage capacity can be adjusted along with cropping conditions by means of balance sheets. Balance sheets are understood as a means of documenting the current amount, and the inputs and outputs of any substance related to a given balance area, e.g., an agricultural farm or field. Balance sheets take into account the existing stock of nitrogen in the soil in order to determine the requirement of fertilizer application at given stages of growth.

The prevention of groundwater pollution by nitrates also requires periodic assessments of the nitrate content of soils. However, this assessment cannot be carried out by means of periodic soil analysis alone, because it is expensive and time-consuming. Model calculations are used which allow an approximate forecast of the content of nitrates in the These are based on "balance models" that compute the successive changes in the balance sheet according to the nitrate inputs and outputs in the root layer throughout the cropping season and consider ongoing processes in the soil during intercropping periods.

The water content at different depths in the soil column is also measured periodically in a number of UN/ECE countries in order to assess irrigation efficiency. Water in excess of plant needs can possibly percolate through the unsaturated zone thus increasing the likelihood of nitrate transport and groundwater pollution.

1. *Mineral fertilizers*

The characteristic feature of mineral fertilizers is to offer nutrients almost exclusively in a form that is directly available to plants. This is a good prerequisite for their actual use, in keeping with the nutrient demands of plants. according to their growth phase and targeted yield; the nutrient content of soils; and the soil's capacity to make nutrient reserves available to plants. This allows a high rate of nutrient utilization by vegetation to be reached and nutrient losses due to leaching, vaporization and immobilization to be largely prevented.

The application of other kinds of fertilizers, such as organic fertilizers, livestock manure as well as green manure, if any, is also important. Within the requirements, shown by the balance sheets, the amount of mineral fertilizers will depend on inputs of other kinds of fertilizer, taking into account the time needed for their conversion into nitrates. It proved to be advisable to fractionate the application. Using a simplified balance-sheet model, such a practice allows to roughly adjust the inputs to the actual demand at growth stages (which require various concentrations in the soil solution) and to the weather conditions which have a decisive influence on the conversion of ammonium and the dissolution of nitrates. An acceptable balance can also be found between the advantage of fractioning the application and the increase in the related operation costs. For example, a good proportion between inorganic and organic components of the fertilization may be helpful. In any case, programmes of applied field research are needed to determine, on a local or sub-national basis, the optimal conditions of application.

Mineral fertilizers, especially nitrates, are very rapidly available in the soil water after application, in contrast to organic ones. The response of the crops is consequently almost immediate. For that reason, many farmers often use chemical fertilizers without reducing the related organic input, if any. Such an over-use can be avoided and comparable levels of yield nevertheless reached, if an adequate fractioning of nutrient applications is carried out.

The main sources of information on how to implement good agricultural practice for farmers in many UN/ECE countries are fertilizer recommendations. In the United Kingdom, for example, such recommendations were published in 1985 in the reference book *Fertilizer Recommendations for Agricultural and Horticultural Crops*. In this book, crop requirement of nitrogen is defined as the point on a curve (which relates financial output from crop to fertilizer input) at which the increase in value of a crop begins to be offset by the increase in cost of nutrients. Computer-based services can make the best use of empirical databases derived from field experiments, and fine-tune the recommendations made in printed sources, such as the above-mentioned reference book. Nevertheless, the principle of assessing the soil nitrogen supply and balancing it with the amount of fertilizer needed to meet crop requirement remains unchanged. It is also important to continue the field assessment of the crop requirement under particular circumstances. Soil mineral analysis (ammonium-nitrogen and nitrate-nitrogen measured in soil samples taken from the soil profile up to a depth of 90 cm) has been used, for example, in some German *Lander (e.g.,* Baden-Wurttemberg), as a direct measure of soil nitrogen supply and potential nitrogen release in the waters.

For the technical and technological implementation of such fertilizer recommendations, it is important to have mineral fertilizers that are easy to handle and to rate. This makes great demands, *inter alia,* on both the fertilizers' consistency and the spreaders' adjustability. Avio-technical distribution of mineral fertilizers cannot meet this requirement.

In general, other precautions can be taken in mineral fertilization, such as:

(a) Taking special care when applying any inorganic fertilizer on fields where there is a risk of run-off to surface water. The risk is greatest when the field is waterlogged or frozen hard.

(h) Avoiding unprotected intermediate open storage on the fields. The risk of pollution from solid fertilizer while in careful storage is relatively low, but pollution incidents, when they happen, can be serious.

(c) Taking special precautions when storing and handling liquid inorganic fertilizer. The storage tank can be designed to suit the type and amount of liquid to he stored. Also, special liquid fertilizer applicators can be

used to avoid dispersion of wind-blown droplets into watercourses.

(d) Preventing nutrient input into subsoil by avoiding deep ploughing.

In greenhouse farming, fertilization according to plant demand and recirculation of high-rate irrigation waters are of particular importance. Since greenhouse horticulture is highly technical, a number of sophisticated technical measures can be applied. The general goal in the Netherlands, for example, is to achieve closed cultivation systems. This means, for instance, that measures are taken aimed at recirculating drainage and condensation water to avoid discharges of contaminated water. The use of drain water for irrigation can help to achieve this goal.

2. *Manure and waste from animal husbandry*

Due to high livestock population, especially their concentration in certain areas, many UN/ECE countries have to deal with large amounts of manure, organic fertilizers or liquid, semi-liquid and solid waste from animal production. In terms of the number of animals per hectare, animal production has become more intensive at two levels: the individual farm and the livestock producing area. In many cases, associated changes in methods and organization of livestock farming have made it comparable to industrial production, and as a result manure has tended to be disposed of as "waste".

The success of measures taken at source and technological add-on measures to overcome these problems decisively depends on how far plant and animal production of a definite area have already deviated from each other. After the implementation of area-dedicated animal husbandry, the following technical and technological measures promote, *inter alia,* water protection:

(a) Providing sufficient, safe and environmentally sound storage facilities, according to structural regulations, in compliance with environmental requirements;

(b) Making available efficient and loss-reducing application techniques (e.g., metering, even distribution; and the reduction of vaporization of nitrogen compounds into the air);

(c) Immediately incorporating the manure into the bare soil (e.g., to minimize surface run-off and gaseous nitrogen losses);

(d) Considering the exact nutrient content, e.g., of liquid manure;

(e) Timing applications as well as possible, also with regard to the weather conditions (e.g., when there is no high radiation, and never in deep snow or on frozen soil);

(t) Providing special feeding to influence the nutrient content of livestock manure (e.g., to adjust the phosphorus content, decrease the protein content, reduce the content of heavy metals);

(g) Separating rain water from dirty water so as to reduce the unnecessary dilution of slurries;

(h) Spreading all types of organic manure only according to crop needs.

If slurry and manure were of a higher fertilizer value per unit volume, there would be more incentive and more possibilities of storing and using it. Pig slurries in particular could be produced in a more concentrated form and with less variable water content by improving the design of housing, animal watering facilities and washing-out systems.

Solid manures include material from traditional straw-covered yards, manure with a lot of straw in it, and solids from mechanical slurry separators. This organic waste will generally contain enough bedding material, or enough dry matter to be stacked. Although solid manures are less likely to cause pollution than slurries, they can make a lot of liquid waste.

Stores that have a concrete base with walls are required; and liquid waste should go into a tank. Although the risk of causing pollution by spreading solid manure is low, surface run-off can occur if rain falls after the waste has been applied.

Supra-regional approaches (e.g., manure trading) as well as sophisticated measures for manure treatment (e.g., aeration, homogenization, clarification, separation) and manure utilization, as strived for in several UN/ECE countries, can be environmentally sound solutions in the short term.

Given that surplus manure in the Netherlands, for example, now totals 20 million tonnes, the Government of the Netherlands has decided to tackle the manure surplus, *inter alia,* through different measures such as reducing the mineral content of manure by reducing the mineral content in feed; stimulating the development of manure treatment and marketing arrangements, including export; and increasing the marketing opportunities for manure by improving its quality.

Apart from direct water quality problems, ammonia released from effluents contributes 20 per cent of the Netherlands' total acid deposition from the air, for example. In areas where intensive animal husbandry is highly concentrated, almost two thirds of the trees are moderately affected by acid deposition. Surface waters are becoming more acid; biological richness is reduced and fish mortality in rivers is increasing. In some areas, an increased acidity of groundwater leads to a remobilization of aluminium and certain heavy metals. These problems are not confined to the Netherlands; widespread similar examples can be found in other UN/ECE countries, for instance, in Belgium, Denmark, Germany and Sweden.

C. The use of pesticides

The strategy for reducing the environmental impact of pesticides can be folinulated in several ways, from pollution prevention at source to the treatment of symptoms like unwanted environmental effects. This strategy may cover measures such as:

(a) Reducing the fundamental need for chemical crop protection by offering alternatives and lowering the disease pressure (e.g., improving crop rotation and producing disease-resistant cultivars); and the use of pesticides only as required, rather than on a preventive basis;

(b) Authorizing the use of environmentally safe pesticides only;

(c) Ensuring the environmentally sound use of pesticides by everyone working with them;

(d) Taking strict precautions to prevent pesticides from spreading beyond the area treated, into water bodies, for example.

The main premise for reducing the need for chemical crop protection is to re-establish the ecological balance in agro-ecosystems by:

(a) Preventive measures to reduce the occurrence of a plague or disease;

(h) Obligatory decrease in the quantity of pesticides used;

(c) Stimulation of research into, and application of, non-chemical alternatives for crop protection.

The first option includes measures such as:

(a) Using high-quality, disease-free plant material or seeds;

(b) Ensuring proper hygienic measures to prevent the spread of disease across different fields;

(c) Limiting the amount of fertilizers given, since a number of diseases are also caused by forcing high yield (an integrated agro-system also means that a new optimal balance is sought between input of pesticides and yield, instead of aiming for high yield only);

(d) Simulating and regulating the extensification of crop-rotation schemes.

The second option includes measures, such as:

(a) Using the correct pesticide and the correct application rate;

(h) Improving the effectiveness of the application methods for pesticides (spraying in rows instead of full fields, weed streakers, periodic maintenance check).

Consideration should be given to the fact that the presence of plague organisms is not in itself a problem, except when it exceeds certain damage threshold limits.

The third option covers, *inter alia:*

(a) Biological methods for pest control, mechanical methods for control of weeds, and integrated plant protection management;

(b) The establishment of environmental and labour-based criteria for biological plant protection agents;

(c) The improvement and intensification of advisory services for these methods.

In addition to human health considerations, pesticides have to be evaluated in the light of their behaviour in soil and water, and for their undesirable effects on organisms in the environment, such as birds, fish and earth worms. This implies the need for prediction of environmental concentration by fate modelling and comparison of the results with environmental standards. To do this, it is necessary to establish a set of clearly defined environmentally based criteria which pesticides, or their main degradation products, must fulfil before bein^g passed for use. These criteria will have to be based on precautionary and ecologically acceptable principles (adequate security for uncertainties, long-term effects, combined toxicity of a number of pesticides and ecological effects thereof) rather than exclusively on the basis of their acute toxicity.

Some of the environmental problems caused by pesticides are due to negligence, such as overspraying a ditch and improper disposal of waste. These can be overcome by ensuring that everybody handling pesticides does so with due regard for the protection of the environment. This means, for instance:

(a) Carefully filling the equipment (preventing spillage; disposing of "empty" cans away from water bodies);

(b) Not making more spraying solution than needed;

(c) Using pesticides on the fields in accordance with application rules (e.g., wind velocity, time of year, correct dosage) and with an eye to preventing environmental pollution (e.g., not spraying beyond the edge of the field);

(d) Maintaining the application equipment in good order (regularly replacing worn-out parts).

In some countries, farmers have to undergo careful training in order to get a "permit of ability to handle pesticides".

There is also a need to:

(a) Carefully rinse used containers and add the rinsing water to the sprayer tank;

(b) Apply the rinsing water from sprayer tanks either to an area of the crop or to sacrificial land;

(c) Use, whenever possible, pressure rinsing equipment for the latter purpose.

Recently the development of collection systems by waste disposal contractors for incineration or chemical treatment has also been taking place. It is obvious that disposal by discharging these rather highly concentrated waste fluids into surface waters is very dangerous for aquatic ecosystems. In the past, in the Netherlands, for example, this has caused a number of fish kills.

Reducing the use of pesticides will in general also lead to a reduction of the amount of pesticides diffused into the environment. In addition, a number of special measures can be taken for this purpose, such as:

(a) Developing and using environmentally sound application equipment (for example, spray drift shields);

(h) Banning application techniques in which there is an unfavourable balance between effectiveness and environmental load (there is, however, a need to establish criteria for new and existing methods);

(c) Prohibiting the planting of crop trees adjacent to the ditch in orchards:

(d) Encouraging the plantation of wind breaks;

(e) Introducing pesticide-free zones (examples of this measure include pesticide-free zones of five to ten metres, as recommended in some German *Lander;* of approximately 0.5 metres next to field ditches and other water bodies as is now being considered in the Netherlands; and of six metres as required in the United Kingdom);

(f) Introducing a disposal and treatment system for pesticide residues and washings.

For greenhouse horticulture, the development objective is for greenhouse cultivation to be completely shut off from the environment. Recirculation of drain water is also the aim. Waste water discharges are prevented as much as possible, or treated and discharged into public sewer systems.

Experience suggests that pesticide stores have to meet the highest standards of design, construction and safety, as well as be fire resistant and flood-proof. This is a basic requirement, as in incidents such as fire, for instance, the use of water can lead to severe pollution of water bodies. These standards require, for example, that liquids should not penetrate the floor, i.e., floors should be impermeable and either below ground level to form a sump as a second retainer, or that there should be a door sill and walls to prevent liquids from passing through and also to contain spillage. Such stores are subject to regular inspection.

III. CODES OF PRACTICE AND GUIDELINES

UN/ECE countries increasingly recognize the necessity and the advantage of establishing codes of good agricultural practice, in accordance with water protection, which as country-wide action guidelines will become the basis for evaluation, support and control.

In the United Kingdom, for example, the 1991 *Code of Good Agricultural Practice for the Protection of Water* is a practical guide to help farmers and growers to prevent water pollution. This Code describes the main risks of water pollution from different agricultural sources. Good agricultural practice is understood as a way of minimizing the risk of water pollution and promoting the continuation of economic agricultural activities. The Code has been made widely available, free of charge, to all farmers. Similar codes exist, for instance, in some German *Lander.* They are also being formulated in some other UN/ECE countries. The Council of the European Communities also decided in 1991 with its Nitrate Directive that member States should establish codes of good agricultural practice for the protection of waters from nitrate pollution, to be implemented by the farmers on a voluntary basis.

Practical experience suggests that the introduction of codes of good practice under the specific conditions of a country requires a series of accompanying measures, such as:

(a) Differentiating the general guidelines and rules at the local level to take into account, *inter cilia,* natural conditions of the respective area;

(h) Providing the proper legal and economic conditions required for practical implementation:

(c) Developing surveillance and monitoring methods in the particular area;

(d) Ensuring that the codes, the local implementation and control method, as well as the legal and economic principles, are approved within the context of socio-economic policies: and that public relations work, education, and well-orientated training are undertaken;

(e) Establishing interdisciplinary working groups, associations or similar bodies to implement water-protecting agricultural practices.

As individual measures cannot be considered in isolation, and as these measures have to be implemented within the framework of a given agrarian policy, the current state of the formulation and implementation of such codes varies greatly in UN/ECE countries. There is a need for utmost concern in the implementation of economically effective and sustainable measures for the reduction of the input rate of substances hazardous to water, even on the soil. The exchange of corresponding guidelines and codes between countries could contribute in this respect. Harmonizing approaches and formulating common principles for developing guidelines could be very beneficial.

IV. LEGAL, REGULATORY AND OTHER MEASURES

Coordination of agricultural and environmental policies is still inadequate. In particular, there is a need for integrating relevant agricultural policies with policies for water protection. Agricultural production has always played an important role in the achievement of a guaranteed food supply for the population. Water management has traditionally fulfilled the function of creating optimum conditions for agricultural production, for example, by irrigation or drainage. However, during the last few years, protection of water from the adverse impact of agricultural activities has increasingly become a matter of particular concern. In general, this should be seen in the context of the ongoing intensification of agricultural production methods over decades. Policies and strategies for the prevention, control and reduction of the adverse effects of agricultural practices on water and the environment in general have, however, so far only to a limited degree been incorporated into agricultural policies. This situation can be improved only through increased co-operation at all levels, nationally, at government level as well as with competent local authorities, and internationally with relevant bodies of the United Nations.

Recognition of the interdependence of agricultural and environmental policies has recently led in some cases to the revision of procedures for policy formulation. There is now a higher degree of public interest in the identification of agricultural targets and objectives to prevent, for example, water pollution.

Successful approaches, which are increasingly accepted in many UN/ECE countries, include the development of river basin management. which guides all forms of land use within a catchment area, and environmental impact assessment for agricultural projects and measures. Integration instruments also cover:

(a) Advisory approaches (e.g., direct advice to farmers, media information to farmers and the general public. farmer-initiated conservation schemes);

(b) Economic approaches (e.g., input taxes, implementation of the polluter-pays principle, land set-aside. direct conservation payments. removal of subsidies);

(c) Legislative and regulatory approaches (e.g., chemical standards, prohibition of undesirable agricultural practices. licensing of practices).

A. Legal measures and regulatory instruments

Input reduction of fertilizers and pesticides into water, or their prohibition, can be achieved by law and regulatory instruments, giving the farmer an incentive to implement better water-protecting agricultural practices. In a number of countries, legislation provides the basis for the introduction and implementation of a code of good agricultural practice.

Laws and regulations require, for example, that farmers or owners:

(a) Refrain from certain activities, such as the ploughing of permanent grassland;

(h) Take specific precautions, e.g., build adequate and safe storage for liquid or semi-liquid manure;

(c) Establish shelterbelts near surface waters;

(d) Do not exceed definite limit values when applying, for example, mineral and organic fertilizers and specific pesticides;

(e) Keep application records to carry out regular checks.

New legislation has been enacted in a number of countries. In Austria, for example, the new 1990 Federal Water Act restricts the maximum annual amount of nitrogen fertilization to 175 kg nitrogen per hectare of land without green cover, and to 210 kg nitrogen per hectare of land with green cover or pasture. The fertilization of garden land (e.g., for vegetable and flower production) is not covered by the provisions of this Act. The given maximum amount of fertilizer applies to the total sum of chemical fertilizers, organic manure, slurry and urine. Within these limits, established by law, each of the nine Austrian federal countries can itself regulate specific periods when fertilization is forbidden or apply more stringent restrictions on the area to be fertilized or the amount of fertilizer per acreage to be applied. The amended Water Act also stipulates the limitation of "manure producing" animals per acreage. Each holder is entitled to up to 3.5 gross animal units per hectare of own land, without special permission.

In Sweden, newly established legislation covers issues such as maximum animal density. From 1995 onwards, only some 1.5 milk cows or 10.5 male breeding pigs will be allowed per hectare of land. These figures were derived from the requirement that the supply of phosphorus from manure throughout Sweden should correspond to the average need of the crops in the crop rotation period. As covering agricultural land by crops during autumn and winter is seen as an effective means of reducing nitrate leaching, decisions were also taken on this subject. From 1992 onwards a certain percentage of all arable land in GOtaland must be held green-covered. From 1995 onwards, 60 per cent of arable land in the whole southern region and 50 per cent of the arable land in other Swedish regions must be green-covered.

Special legal measures and regulatory instruments are also required for the control and authorization of pesticides and the handling of pesticide waste. With respect to the recent amendment of the EC *Council Directive of 15 July 1991 Concerning the Placing of Plant Protection Products on the Market* (91/414/EEC), for example, which is intended to facilitate the marketing of pesticideson the basis of recognition of licences in other member States, it is also essential to arrive at a harmonized assessment method based on uniform principles and criteria. As far as the whole UN/ECE region is concerned, there is the need to:

(a) Develop and harmonize reliable and objective risk assessments for the legislation of pesticides;

(h) Ensure that the same environmental standards are applied in all UN/ECE countries;

(c) Regularly review the approval of pesticides, based on the assessment of the risk they pose to groundwater, surface water and related ecosystems; and phase out those pesticides with a proven adverse effect on water;

(d) Take into account specific restrictions, for example, in vulnerable groundwater zones and other sensitive areas, when using pesticides.

B. Education, training and advice

In recent years, aspects of water protection in particular and environmental protection in general have increasingly been incorporated into agricultural education and training programmes. In Germany, for example, aspects of environmentally sound agricultural production including the appropriate use of fertilizers and pesticides are being included at all levels of education and vocational training in the field of agriculture. For instance:

(a) Rules for vocational training and curricula for vocational schools stipulate that trainees should receive training in the prevention of environmental damage, protection and maintenance of water bodies, and prevention of erosion.

(b) Curricula at agricultural technical colleges make environmental protection an integral part of teaching. This includes teaching in the fields of environmentally sound production, protection of the landscape and of water bodies. Regulations covering examinations for Master programmes require that proof should be given of the relevant skills and knowledge.

(c) Education in the field of environmental protection is also an integral part of agricultural studies at colleges and universities. Aspects of water protection, proper fertilization according to plant demands, and responsible utilization of pesticides are covered in particular in the specialized areas of ecology and plant production.

Experience suggests that training and advice produce the best effects if relevant measures are based on the principles of understanding and voluntaryism. These measures may offer the farmer a great variety of general rules, guide values and codes from which the farmer may find appropriate water protection methods adapted to his specific local conditions and production scheme. However, an innovative look at the issue is also required. This poses particular demands on instructional, consulting and educational work.

In many UN/ECE countries, consulting systems have been established, especially for fertilizer application, plant protection, business economics and sprinkler irrigation. The gradually increasing acceptance of these systems was primarily due to their economic benefits.

Plant-growing consulting services still tend to overlook ecological considerations. Problems of business management continue to be the focus of these services. Furthermore, advice services on the use of mineral fertilizers, manure and pesticides were aimed, in some instances, at achieving higher yield only. Nowadays, these services are being revised in some countries. In the Netherlands, for example, they are now being revised in order to include environmental aspects.

Experience gained in a number of instances indicates the need for agricultural consulting services which lay more emphasis on the consideration of water, soil and the overall environmental conditions both in plant protection and in consulting services related, *inter alia,* to fertilization and sprinkling irrigation. Training in the correct use of pesticides, including methods for the control of pesticide-resistant species, is also needed. Experience has shown, for example, that overspraying, which is one of the main causes of diffuse water pollution from pesticides, was mainly due to a certain resistance on the part of farmers to adopt new practices. All this poses greater demands on the consulting systems (e.g., better foundation through environment-dedicated and locally differentiated field trials) and requires experienced consultants.

The implementation of appropriate measures requires both well-trained farmers and (in case of need) investment and modification to total farm restructuring (i.e., the farmer takes definite steps, for which he expects public compensation). The need for better consulting services and for the enactment of legislation leading to strict limitations also calls for appropriate regulations in economic and agrarian policy.

In the United Kingdom, for example, the Ministry of Agriculture's advisory arm (ADAS) has for many years been advising farmers on appropriate fertilizer application, with a focus on the reduction of nitrate leaching into water. The advice has been available through various means over the years. More recently the following measures were taken:

(a) The 1991 *Code of Good Agricultural Practice for the Protection of Water* (which mainly focuses on disposal of animal waste rather than on inorganic fertilizers application levels) has been made widely available to farmers free of charge;

(b) The services of "Fertiplan", a field-by-field commercial fertilizer recommendation service, have also been made available free of charge in areas sensitive to nitrate pollution;

(c) Advice on appropriate levels of fertilizer were set out in the 1985 reference book *Fertilizer Recommendations for Agricultural and Horticultural Crops.*

Partly as a result of the advice provided in the United Kingdom, autumn nitrogen applications to winter cereals and oilseed rape have fallen sharply. In addition, total nitrogen applications to arable crops have stabilized or even slightly decreased although there was an increase in agricultural yield. Advice has proved to be a very useful means of reducing applications of fertilizer to the crop requirement level. Also, the pilot Nitrate Scheme (see the section on monitoring and evaluation), set up in 1990 as a means of testing the effectiveness of agricultural measures on nitrate leaching, prior to the introduction of the EC Nitrate Directive, included an intensive advisory campaign in areas identified as nitrate advisory areas.

As concerns advisory systems in Sweden, all agricultural enterprises with more than 25 animal units (approximately 18,000 in number) have been offered advice free of charge. This advice is aimed at establishing crop production plans for all these farms, as well as manure and inorganic fertilizer plans. From 1992/1993 onwards, free advice will also be given to farms with less than 25 animal units, if these are located in sensitive areas regarding water and the general environment.

C. Economic instruments

The urgency of water protection has led to initiatives for the adaptation of agrarian policy to new requirements in market policy and economy in UN/ECE countries. A number of countries, especially member States of the European Community, are making a series of attempts to bring economic regulations and agrarian policy aimed at the containment of surplus production in line with water protection measures and measures to protect the environment in general.

The implementation of economic instruments within the framework of given national regulations causes complications, for example, in terms of exact financial regulations, distribution of environmental protection costs and the achievement of long-term stability. The same is true for financial support granted for the building of storage facilities, application equipment or manure treatment plants in animal production.

Despite the extremely wide variety of particular national economic regulations, almost all countries have one problem in common: the distribution of costs. Financing mechanisms such as the following have been put forward:

(a) Imposing a tax on mineral fertilizers and pesticides.

(b) Making waterworks compensate the farmer for use restrictions in officially assigned drinking-water protection areas (in particular when these restrictions are more severe than those usually applied in drinking-water protection areas due to specific local conditions). In this case, water prices are raised for cost reapportionment among consumers.

(c) Paying, from general budget subsidies and compensatory payments, for the imposition of agrarian production which protects water resources and the environment in general.

(d) Making the consumers pay higher prices for higher quality agricultural products, thus enabling the consumer to benefit from high-grade produce and, at the same time, promoting agrarian production in keeping with requirements for the protection of water and the environment in general.

(e) Imposing progressive taxes on surpluses of liquid manure and other polluting waste from animal production, especially for numbers of livestock considered excessive for the locality.

(f) Paying compensation for extensification measures.

(g) Reducing subsidies or charging for practices which lead to the pollution of water and other environmental media.

The above-mentioned models differ greatly from country to country in so far as the polluter-pays principle is concerned, which cannot easily be applied to agricultural production. Financial support from other policy areas is given to farmers who comply with the requirements of good agricultural practice. As concerns the European Communities' negotiations on the reform of the common agricultural policy (CAP), some member States expect greater environmental benefits as well as a reduction in agricultural output from this undertaking. For example, it is proposed that direct payments to farmers under the CAP should be made on condition that the minimum environmental protection requirements are respected. These proposals are seen as a means of ensuring that farmers who receive financial assistance under the CAP protect the environment.

D. Monitoring and evaluation

In general, monitoring systems aim to provide information in order to assess the current state of changes of water quality; detect water pollution to allow for early control measures; identify endangered areas; and to assess the effectiveness of protective and restorative measures undertaken.

Experience suggests that water pollution monitoring has to be more detailed the greater the threat to the water body concerned, and the greater the urgency of control measures and/or the need to protect the water body.

The development of monitoring strategies has usually been driven by the needs of water legislation. This has in the past resulted in a rather piecemeal approach to monitoring. As regards the control of water pollution from agricultural practices, specific monitoring requirements arise. Monitoring is to be carried out so that it reflects the diffuse nature of this kind of pollution by taking into account, *inter alia,* both the seasonal and local variations in the application of pesticides, fertilizers and/or manure. This may require in most instances that water-quality monitoring is carried out not only in major surface and groundwaters potentially receiving inputs of substances from diffuse sources, but also in small creeks and ditches hydrologically connected with those waters. Furthermore, specific requirements arise regarding the choice of parameters subject to detailed monitoring in waters and/or early detection of adverse effects. Some countries report that the use of bio-monitoring systems is a useful tool for early detection of summary. adverse effects of the emission of substances on inland waters and on the aquatic life that they support. Nevertheless, there is a need to apply specific analytical methods to detect the presence of substances in water on a chemical-by-chemical basis.

Monitoring of pesticides in fresh water and soil is less advanced than monitoring of nutrients and heavy metals from agricultural activities. If pesticide monitoring is tobe of value to regulatory bodies and research, then investment is required for the development of, *inter alia:*

(a) Multi-residue analysis techniques.

(h) Analytical techniques capable of resolving pesticide concentrations below the drinking-water standard in natural water (which contains suspended solids and other interfering organics) and sediment.

(c) Biological indicators, both as general in-field pollution indicators and as pesticide-specific tests, e.g., immuno-assay techniques. The latter promise to provide quicker and cheaper methods of analysis.

(d) Groundwater monitoring techniques, to provide a better means of distinguishing the temporal processes of groundwater contamination and, in particular, to determine whether the slow leaching of present-day applications will lead to the future contamination of deep aquifers.

Since there are a few hundred pesticides in use in the UN/ECE region, monitoring strategies on pesticides need to target those active ingredients which are likely to be found in surface and groundwater in the area of concern. Models based on the physico-chemical properties of pesticides in combination with pesticide usage surveys based on data collected on farm use can be used to this end.

Experience from the United Kingdom also suggests that monitoring strategies on some pesticides are being tailored to hydro-meteorological conditions. For example, pesticide movement through the soil can be driven by rainfall events as has been documented for atrazine. High concentrations in rivers can also be associated with periods of high field drainage, as has been recorded for the agricultural herbicide isoproturon. Such is the importance of river flow that, in the United Kingdom, monitoring strategies for certain pesticides will be tailored to them. For others, such as isoproturon, all year round monitoring will be required.

In addition, it will be necessary to develop monitoring methods for both fertilizers and pesticides starting from the supervision of farm-based matter inputs and outputs. Such methods include, for example:

(a) Compulsory records documenting any important agricultural activity related to the concrete field units of a given farm or from certain field or plot sizes upwards;

(b) Proper balancing of the plant-soil-water system according to the particular plot or farm;

(c) The elaboration and control of limit or control values of soil properties according to the particular location and land utilization;

(d) A critical look at the farm's organization to determine whether the actual agrarian production is generally compatible with water protection requirements.

As concerns drinking-water protection zones, the incorporation of the above-mentioned methods into agreements between farming and water-supply enterprises or associations related to both agricultural consulting and direct cooperation, has been extremely effective.

The EC Nitrate Directive also requires EC member States to introduce such guidelines into national law, and accordingly to undertake relevant control. An appropriate transitional period is set to both facilitate structural adaptation processes in agriculture and allow the control mechanisms required to be developed.

In the United Kingdom, for example, ten nitrate sensitive areas (NSAs) have been designated that cover an area of some 10,700 hectares. A comprehensive monitoring programme is carried out in these NSAs. It has four components:

(a) Measurement of nitrate leaching on selected fields, using porous ceramic cups;

(b) Deep coring (drilling in such a way that a solid core is extracted) of the unsaturated zone down to 10-15 m below the surface in selected NSAs;

(c) Individual field data collection on cropping, fertilizer input and other management practices affecting nitrate leaching;

(d) Measurement of nitrate concentration in water abstracted from boreholes.

The scheme is voluntary and farmers were invited to enter into five-year agreements which began in either 1990 or 1991. The scheme requires farmers to follow specified practices designed to reduce nitrate leaching. It comprises two parts:

(a) A basic scheme of measures under which farmers are required to adjust existing practices. The measures include, for example, limits on the timing and level of fertilizer applications, constraints on grassland ploughing and cover crop requirements.

(b) A premium scheme of measures under which farmers are required to convert from arable land to grassland or from grassland to woodland.

Each farm will be visited at least twice during the life of the five-year agreement and farming practices and records of fertilizer applications checked for compliance. In case of breach, the payments may be withheld or recovered and, ultimately, the agreement may be terminated.

The results of this programme are expected to enable the evaluation of the extent to which agricultural measures can reduce nitrate leaching. A socio-economic evaluation is also scheduled during the life of the scheme. This will be used to assess the effects of the scheme on those who join it, notably on farm costs, income and production and on the local economy. It is also intended to assess farmer attitudes to tackling the nitrate problem. In Spain, a similar scheme has been in force in selected areas since 1988.

In the Gelman *Land* Baden-Wurttemberg, a special Order was enacted which is applicable to water protection areas. This Order, entitled SCHALVO *(Schutzgebiets- and Ausgleichsverordnung)*, contains binding obligations on the maximum content of soil nitrogen in water protection areas in addition to obligations for the regular monitoring of this nitrogen content. In case of breach, compensation payments are withheld or the recipients must return the payments received.

Models describin[g] the dynamics of nitrogen compounds and pesticides in the soil-water-plant system provide a means of improving control, monitoring and evaluation.

It is current practice, for example, to base nitrogen models on soil data gathered at the beginning of a cropping season as well as on periodic soil analysis to adjust the model, when relevant. This approach is, for example, followed by nitrogen models developed in France.

Usually, nitrogen models require the following input data: organic and chemical fertilizers, including green manure if relevant; crop residues dug into the ground; atmospheric inflow; nitro[g]en content of transversal water flow in the upper layer; and nitrogen fixing by legume crops, if relevant. Outputs of models cover, *inter alia*, the crop or natural vegetation consumption; the horizontal transfer by the transversal water flow in the upper layer; the denitrification process in the soil (as a function of the climatic and soil structure conditions); and the leakage to groundwaters (indicating the potential risk of their pollution).

Current day-to-day agricultural management is mostly based on simplified nitrogen models which have been developed for given crops, chosen among the most common at a given local level. Using rough estimates of a limited number of the most significant parameters (based on preliminary calibrations according to the local conditions and soil analysis data) such simplified models can be processed by microcomputers.

In France, tables are used for rough estimates of important variables, including estimates of the plant consumption according to the crop, its stage of growth and the climatic conditions. Such methods are to be adapted to the specific features of the various crops of the crop rotation.

Simplified models, elaborated by research institutes of the Russian Federation and Ukraine have also been used in day-to-day management practices in these countries. These models produce, with sufficient accuracy, information on the effect of agricultural practices on surface, drainage and groundwaters, and enable the assessment of effects of water protection measures and/or the risk of pollution under extreme conditions, such as accidents. These models are run with a moderate set of input data.

Model development for pesticide transport through ecosystems is not as well advanced as those for nitrate movement. Such models should be more complex than nitrate models. Additional aspects, such as the physico-chemical properties of the pesticide; weather patterns (i.e., rainfall and dry periods); degradation rates under different soil conditions; pesticide partitioning between water, soil and sediment; transport processes within streams; land management techniques (drainage, etc.); timing of application; type of ground cover and extent of root development; soil and subsoil structure; aquifer structure; and position of surface-water drains, ditches and streams should be incorporated. In many cases, these models are subject to further research.

E. Research and development

Extensive research has been undertaken to understand and to cope with conflicts between intensive farming and the need to protect water and other environmental media. However, there is still a series of open problems calling for basic and applied research. In particular, there is a need to develop forms of integrated land farming that are compatible with both the protection of water and the general environment and agricultural development, according to socio-economic requirements. The latter refers to less intensive land farming methods that remain to be developed in the long-term perspective. There is also a need for more research on effective control methods and monitoring techniques in order to assess compliance with legislative measures and regulations.

Areas of research and development are extremely wide and cover, *inter alia:*

(a) Further exploration and development of appropriate less intensive farming methods;

(h) Development and supply of appropriate farming equipment (e.g., equipment for distribution and soil cultivation) and products (e.g., environmentally safe pesticides, fertilizers which can be applied in exact doses);

(c) Development of reliable sampling and analysis techniques (e.g., for soil and plant samples);

(d) Reasonable integration of such sampling and analytical techniques into control and monitoring strategies;

(e) Deduction\ and improved technical and technological foundation of such control and monitoring strategies, especially their improved scientific exploration.

The further development of appropriate prognostic models on the dynamics of nitrogen compounds in the soil-water-plant system as well as of simplified prognostic models for day-to-day use under field conditions is also the subject of research. At present, most prognostic models require the knowledge of cause-effect relations, for example, of chemical processes in the soil and the soil water. In many instances, the accuracy of the available information is only limited. These models also require many parameters to be assessed, a great capacity of data processing and regular and frequent comprehensive soil analysis to run or adjust the model. Such conditions can hardly be met at the farm level. However, such models are used as an instrument for further research and development to improve the knowledge of processes in the soil-water-plant system, and as a tool to calibrate simplified methods which are used at the farm level. Experience also suggests that an integration of field observation and mathematical modelling provides a useful tool for making prognoses more objective.

In the field of pesticide pollution research, activities on control measures have in the past concentrated on methods for improving both pesticide specificity and application with the purpose of improving efficiency. Reductions in pesticide usage and the development of less persistent, toxic and bioaccumulative formulae have not in the past been driven by the need to protect water. If this is to become a tangible aim, then aspects of water protection should become an integral part of the following areas of research:

(a) Changes in the formulation of both the active ingredient and its coformulants;

(b) Application techniques including continued improvement in pesticide tar^g^eting to reduce wastage and hence immediate water pollution problems;

(c) Change in strategy from prophylactic to reactive pesticide usage;

(d) Model development for pesticide transport through ecosystems, as well as the investigation of the fate and risk associated with the metabolites of pesticide degradation. (The complexity of the latter issue will only come to light once all pesticides have been fully evaluated.)

The further strategy in the field of pesticide research leads to and forms an integral part of:

(a) Integrated pest management (introduction of disease-resistant crops, use of biological control measures, reduced pesticide usage and improved pesticide management).

(b) Extensification, in particular to ensure that the non-crop land management techniques adopted do not pose a greater environmental risk in terms of the amount of pesticide and fertilizer required to maintain them.

(c) Atmospheric transfer and the structure and functioning of buffer zones under different agricultural conditions.

(d) Field management techniques, to determine how various land management practices affect pesticide leaching. Concomitant with this, research is required on the effects of temporal variation in application and on the importance of the physical and chemical characteristics of pesticides on the leaching processes.

(e) Disposal techniques designed to reduce the environmental impact of pesticide waste, e.g., by filtration and degradation.

There is also a need for further research and development on issues such as improved technologies to treat unavoidable or locally excessive amounts of waste, for example, from animal production or greenhouse farming. Furthermore, reliable information on the manifold socio-economic problems arising from a step-wise transformation of intensive agriculture into an environmentally sound agricultural production is needed. This research work requires interdisciplinary activity in various subject areas and institutions as well as research-promoting strategies and the exchange of experience, findings and information among countries.

CONCLUSIONS

Many UN/ECE countries have, in the past decades, made tremendous technological advances in agriculture, resulting in a vast increase in production. This was made possible, among other things, by the intensified use of fertilizers and pesticides. However, adverse effects of this agricultural development, such as the eutrophication of inland waters through excessive inputs of phosphorus compounds, the pollution of groundwater and surface waters with nitrogen compounds and pesticides, and acidification have also become apparent, posing a serious threat to aquatic and terrestrial ecosystems as well as to the public water supply.

Farmers have in recent years become more aware of their responsibility to prevent, control and reduce these adverse effects on water and the environment in general. Remedial action was undertaken in some countries through action programmes and the introduction of good agricultural practice, adapted to specific local conditions. In a number of instances this has led to new legislation, regulations related to the new agrarian policy and to economic tools for their implementation. Improved consulting services, education and training on new possibilities provided by advanced methods to prevent pollution at source, in addition to add-on measures, have also been positive results of good agricultural practice.

Achievements in the prevention, control and reduction of environmental pollution originating from agriculture vary among UN/ECE countries, and there are a considerable number of areas where further action is required. In many instances, information on technical measures to prevent and control pollution is adequate. Lack of implementation is, however, more often the key problem, for economic or policy reasons.

Areas for further action or improvement relate, in particular, to:

(a) Better coordination or even integration of agricultural policies with environmental protection policies and land-use planning.

(h) Assessment of the impact of proposed measures in the agricultural sector on all environmental media, since many measures still address the impact on water in isolation from the impact on soil, air or the living environment.This has a specific bearing on the authorization of pesticides.

(c) Elaboration and implementation of codes of good agricultural practice. Such codes should take into account relevant national legislation and be implemented nationwide to ensure that the basic environmental protection requirements are met. Sensitive areas should be subject to additional precautionary measures. The ex-change of corresponding guidelines and other relevant information between UN/ECE countries and the harmonization of approaches would be very beneficial.

(d) Reorientation or development of new economic tools, both at the national and international levels, as there is a need to bring agrarian policy tools, which are nowadays mainly aimed at containing surplus production, in line with protection measures for water and the environment in general. Further,more, mechanisms for financial regulations and distribution of environmental protection costs are not yet sufficiently developed.

(e) Development of monitoring and registration systems, as there is a growing need to acquire more information on the present and future state of the environment regarding pollution by agro-chemicals. There is also a need to improve knowledge on faiin-based inputs and outputs and to monitor compliance with existing legal obligations and codes of good agricultural practice, and to use monitoring and surveillance as a feedback system by taking into account the data gathered, for example, when reviewing approvals of pesticides, determining the effectiveness of codes and assessing whether these codes need to be reviewed.

(f) Education, training and consulting, as in many instances these measures are still designed to achieve higher agricultural production without due regard for the prevention, control and reduction of the adverse impact of agricultural practices on the environment.

(g) Research and development, as there is a need to further develop sustainable and environmentally sound farming systems. This includes, for example, research into alternative and/or integrated plant protection methods, appropriate fertilization methods, waste management, and efficient farming equipment.