GROUND-WATER POLLUTION BY NITRATE

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ABSTRACT

Based on analytical data from three different institutes, the pollution of ground water with nitrate in the Federal Republic of Germany is quantitatively discussed. Strategies for nitrate reduction and ground-water protection are proposed.

RESUME

A partir de données analytiques de trois institutions différentes, la pollution en nitrate de l'eau souterraine est discutée quantitativement. Diverses solutions pour la réduction du nitrate et la protection de l'eau sont proposés.

INTRODUCTION

Ground-water pollution usually occurs unnoticed and is often detected very late, because sample collection is only possible by installing several observation wells. Supra-regional screening of ground-water quality in the Federal Republic of Germany is mainly based on monitoring the more than 6,000 water plants, which exploit ground water, and the nearly 2 million private wells for drinking water. The well depth for small water plants (less than 100,000 m^3/a) and private wells in most cases lies between 3 and 10 meters. Therefore they are extraordinarily sensitive to pollution, since the protecting soil layer is often relatively thin. Large water plants obtain their water mainly from deeper ground-water stocks down to some hundreds of meters. In areas of conventional and - above all - of intensive agricultural production, increased pollution of water sinking through the soil has been observed. Hydrochemistry of sinking water can be considerably altered during subsoil passage. Some data from the drinking-water data system BIBIDAT of the Federal Bureau of Health (Federal

Republic of Germany) point to an increase in nitrate content of ground water since the nineteenfifties, especially in the following regions:

Table 1

Region	Main agricultural use
Lowlands of Northern Germany	potatoes, turnips
Lower bay of the Rhine river	turnips, vegetables
Upper valley of the Rhine river	wine, vegetables
Valleys of the rivers Rhine, Main, Neckar, Mosel	wine
Lake of Constance	hops
Munich	hops

Up to now, nitrate pollution of raw water cannot be removed under the present technical methods without increasing costs. New toxicological data have stirred the EC to fix the nitrate tolerance for drinking water at 50 mg/l for all member states. The West German legislature must declare this value to be legal at the latest by 1982 (previously 90 mg/l).

HEALTH RELEVANCE OF NITRATE

While primary effects of nitrate on man are very trifling (e.g. irritation of the mucous membrane of the gut), secondary effects of the metabolism of nitrate to nitrite imposes considerable risk: nitrite blocks haemoglobin in the red blood cells and inhibits oxygen transport. Especially infants in their first months are endangered (COMLY 1945). The relationship between infant methaemoglobinaemia and nitrate content of drinking water in the Federal Republic of Germany was first published by SATTELMACHER (1962). A sufficient safety factor seems to be offered, in our opinion, by a level of 10 mg/l for infants (GABEL 1982). As a tertiary effect, the reaction of generated nitrite with special amine/amide compounds in food or medicine has to be taken

into account. Here, N-nitroso-compounds can be formed which may be potent carcinogens in animals. Therefore, a cancer risk for man cannot be excluded (SANDER 1968).

SOURCES OF NITRATE BURDEN

Doubtlessly, natural biotopes (fens, ...) may cause considerable ground-water pollution with nitrate. As a more important cause the extent and trend of agricultural nitrogen output in different regions of the Federal Republic of Germany is still under discussion.

Two sources of the excessively washed-out nitrate have to be distinguished:

1. manuring while ignoring demand (over-manuring, ...)
2. "necessary" manuring in intensive culturing (high yield varieties, ...).

The nitrogen contents of agriculturally used soils (to 20 cm depth) vary from 600 to 12,000 kg N/ha (1 ha = 2,47 acres), of which nearly 95 % is bound organically (mainly in humic compounds, but in biomass of plants and microorganisms, too). The small fraction of mainly less than 5 % exists in a plantavailable form. The great nitrogen depot of the soil is submitted to permanent turn-over by supply, loss and deprivation, during which a part of the organically bound nitrogen is mineralized and available to plants. Consequently, a distinct part of this (dissolved) nitrogen is washed out, even following organic manuring or none at all; the extent of washing out is modified by the mode of manuring.

The degree of nitrate pollution of the ground water in the Federal Republic of Germany seems to be larger than had been supposed some years ago. This essay intends to show that an appreciation of the problem is causing a change in water politics which has just started, and that regional problems can expand to a supra-regional super-problem. A quantitative assessment of the specific problem will be attempted.

METHOD

Nearly 2,000 drinking and well water samples of the entire Federal Republic of Germany have been examined for nitrate content. Sample collection was executed partly by our institute, but mostly by private persons, using our sample bottles and sampling instructions. Randomly collected control samples failed to turn up sampling errors. Continuous analysis showed that nitrate reduction in the same sample did not occur within three weeks. Nevertheless, samples were fixed with Korosolin^{R}.

Analysis was conducted as follows: a pre-test with Merckoquant^{R} in order to obtain the concentration range and dilution factor, then exact analysis with Na-salicylate (MERCK) with photometrical detection. Randomly selected samples were analyzed in parallel with a colorimetric test by MACHEREY-NAGEL and with brucine (MERCK).

For further control, some samples were analyzed as well in two external institutes (using Na-salicylate (A) and ionchromatographic methods (B)). Agreement in the range of analytical error was obtained (Standard deviation of our method: 4,5 %). The following table shows selected double sample results:

Table 2: Comparison with external institutes in nitrate analysis

Sample-No.	Inst. A	Inst. B	Bremen Env. Inst.
116	93.4	88	90
182	149.4	145	142
209	95.6	96	94
232	92.9	92	92
295/7	102	-	104
302/7	114	-	114

Table 3: Permanent or periodical transgression of the nitrate tolerance limit in public water supplies in Bavaria

permanent

Regierungsbezirk Unterfranken
Landkreis Kitzingen:
Wasserversorgung Gemeinde Sommerach

periodical

Regierungsbezirk Niederbayern, Landkreis Dingolfing-Landau:
- Genossenschaftliche Wasserversorgung, 8384 Kugel

Regierungsbezirk Oberpfalz, Landkreis Neumarkt i.d. OPf.:
- Stadt Berching (Ortswasserversorgung Hennenberg)
- Stadt Regensburg: Regensburger Energie- und Wasserversorgungs-AG und Co. KG (Teilversorgung Kagern)

Regierungsbezirk Oberfranken, Landkreis Bamberg:
- Zentrale Wasserversorgung Lisberg
- Zentrale Wasserversorgung Trabelsdorf

Regierungsbezirk Mittelfranken, Landkreis Roth:
- Wasserbeschaffungsverband Rohr (Ortsteil Weiler)

Regierungsbezirk Mittelfranken, Landkreis Weißenburg-Gunzenhausen:
- Westheimer Gruppe
- Trinkwasserversorgungsanlage Reuth

Regierungsbezirk Unterfranken, Landkreis Kitzingen:
- Gemeinde Volkach, zentrale Wasserversorgung Ortsteile Köhler und Astheim
- Wasserversorgung Marktbreit

Regierungsbezirk Schwaben, Landkreis Augsburg:
- Zweckverband zur Wasserversorgung der Lechfeldgemeinden, 8931 Graben

RESULTS

Upper Values and regional differences

Nitrate content in ground-water stocks from small dephts shows considerable seasonal variation. One reason for this is the washing out of nitrate from cultivated soil, depending on seasonally varying precipitation amounts and vegetation rhythms. In the Federal Republic of Germany, short term upper values up to nearly 400 mg/l nitrate have been found in public drinking-water supplies - a concentration of nitrate that means acute health risks for infants. Samples taken one and two weeks later showed "only" 114 mg/l.

The importance of seasonal oscillation in nitrate concentration can be seen in table 3. Here, the districts of the public water supplies in Bavaria with permanent or periodical tolerance limit transgression (as measured so far) are listed (BAYERISCHER LANDTAG).

In order to get a picture of such maximal burdens at the end of a long hot summer, the weekly magazine "STERN" started a campaign all over the Federal Republic of Germany. Following the instructions of the magazine, 451 water samples of large (> 1 mio m^3/a), small (1 mio - 0.1 mio m^3/a) and the smallest (< 0.1 mio m^3/a) water plants were taken and then analyzed partly in our institute, and partly in the Institute Fresenius in Taunusstein. 36 of the analyzed samples showed a nitrate burden of more than 50 mg/l (8 %). All of these water plants were exploiting ground water.

REGIONAL PROBLEMS

In one of the most important wine-growing areas of the Federal Republic of Germany (around Würzburg) 26 randomly selected samples from different public water supplies demonstrated that 31 % (= 8 samples) had nitrate contents above 50 mg/l, with a maximum concentration of 180 mg/l (Sommerach).

Distinctly higher nitrate levels were generally found in private wells in areas of intensive cultivation. 79 well water samples around Krefeld showed maximum concentrations of more than 300 mg/l; 73 % of the analyzed samples were above 50 mg/l. Sample collection was carried out in October 1982. The influence of "surface usage" (buildings, agriculture, forest, ...) is regarded, too. See figure 1.

Until November 1982, nearly 980 water samples were sent to our institute for analysis. These samples were derived from public supplies and private wells. Sample analysis was made by a quick test, and samples containing more than 30 mg/l were analyzed additionally with a semiquantitative colourimetric test in order to check the first result.

Fig. 2 gives a survey of regional distribution of drinking water and well water containing more than 30 mg/l nitrate. In order to extend the data basis, the places with periodically or permanently occurring contents of more than 50 mg/l nitrate in drinking water were incorporated from BIBIDAT as well.

Fig. 2 compares intensity of agricultural use with the nitrate burden of well and drinking water above present tolerance limits. The accumulation of high nitrate levels in wide areas of northern Germany (mainly well water) without or with little intensive agriculture is very striking.

CONCLUSION

As a result of an inquiry by the Ministry of Food, Agriculturé and Forest in North Rhine-Westphalia, 7,9 % of 1,162 water plants had a nitrate level of more than 50 mg/l. Especially in the district of Düsseldorf, more than 50 % of all private wells contain more than 50 mg/l nitrate (VORLAGE 3/984).

The evaluation of BIBIDAT (3,000 water plants till 1978) showed 6.6 % of the consumers to be supplied with drinking water with more than 50 mg/l nitrate (AURAND). 800 water samples of public supplies (1972-1980) showed tolerance limit transgression (50 mg/l) in 4.7 % of all

samples (DARIMONT 1981).

In regard to the existing concentration oscillations - at the moment - nearly 10 % of the German population is probably supplied with water containing - periodically or permanently - more than 50 mg/l nitrate. In addition, some 10,000 people with private wells will partly be supplied with drinking water containing more than 50 mg/l nitrate.

In regard to the problems of the near-surface ground-water stocks and of the analysis of selected water exploiting areas and, last but not least, in regard to the still increasing use of synthetic fertilizers in agriculture (OBERMANN 1981), the identification of a still increasing number of affected ground-water supplies in the next coming years is virtually a fact.

The regions of problems in water quality in northern Germany depicted in fig. 2 cover the regions of intensive animal breeding. Here, great amounts of organic waste water (Gülle) from the animal farms are used for manuring. Washing out of this organic manure mainly depends on the amount applied, the date of application, the use of manured fields, soil character and climatic circumstances. N-washing out following animal waste water disposal ranged from 7 % in spring to 30 % in autumn (VETTER 1977/78). In some districts of northern Germany the production of animal waste water exceeds that used for meadows by more than 100 %.

In the district of Vechta, animal farm waste water usage results in a manure density of 250 kg N/ha. Because of the lack of capacity for interim storage, the waste water is often applied even in winter, resulting in a reinforcement of ground-water pollution (VETTER 1977/78).

The risk of high nitrate contamination of drinking water is most urgent for private ground-water wells in areas of animal breeding. Here, maximum nitrate values of up to 400 mg/l have been found.

STRATEGIES FOR A SOLUTION

Any basic strategy for solving a problem has to be oriented towards the responsibility of the producer of the damage. The first and most important measure is avoidance of nitrate input in water production areas (agriculture, animal wastewater disposal). Problems will not be solved only by limiting manure in the protection zones I, II and III of water plants - as far as they do exist at all; more than 50% of west German water plants have absolutely no protection zones. The strategy of limiting fertilizer input has to be accompanied by a coordinated transition from conventional to extensive agriculture, if agriculture takes place in these zones at all. This seems to be no economic problem facing agricultural surpluses.

At the moment, water management seems to prefer another strategy: the mixing of water burdened heavily with more or less not burdened (ZfkW 1982), and supra-regional connection of water supplies. Both avoidance strategies generate new problems (e.g. enforcement of centralizing and centralism in public water supply and reinforced use of industrially burdened surface waters) (LAHL 1982).

Ground-water pollution is as a rule a damage for years and decades. No one can foresee the social relevances of ground-water pollution in the future. Looking at the future we will offer to our children, ground-water pollution with anthropogenious contaminants is no longer only an economic problem of water purification technologies, but mainly an ethical one.

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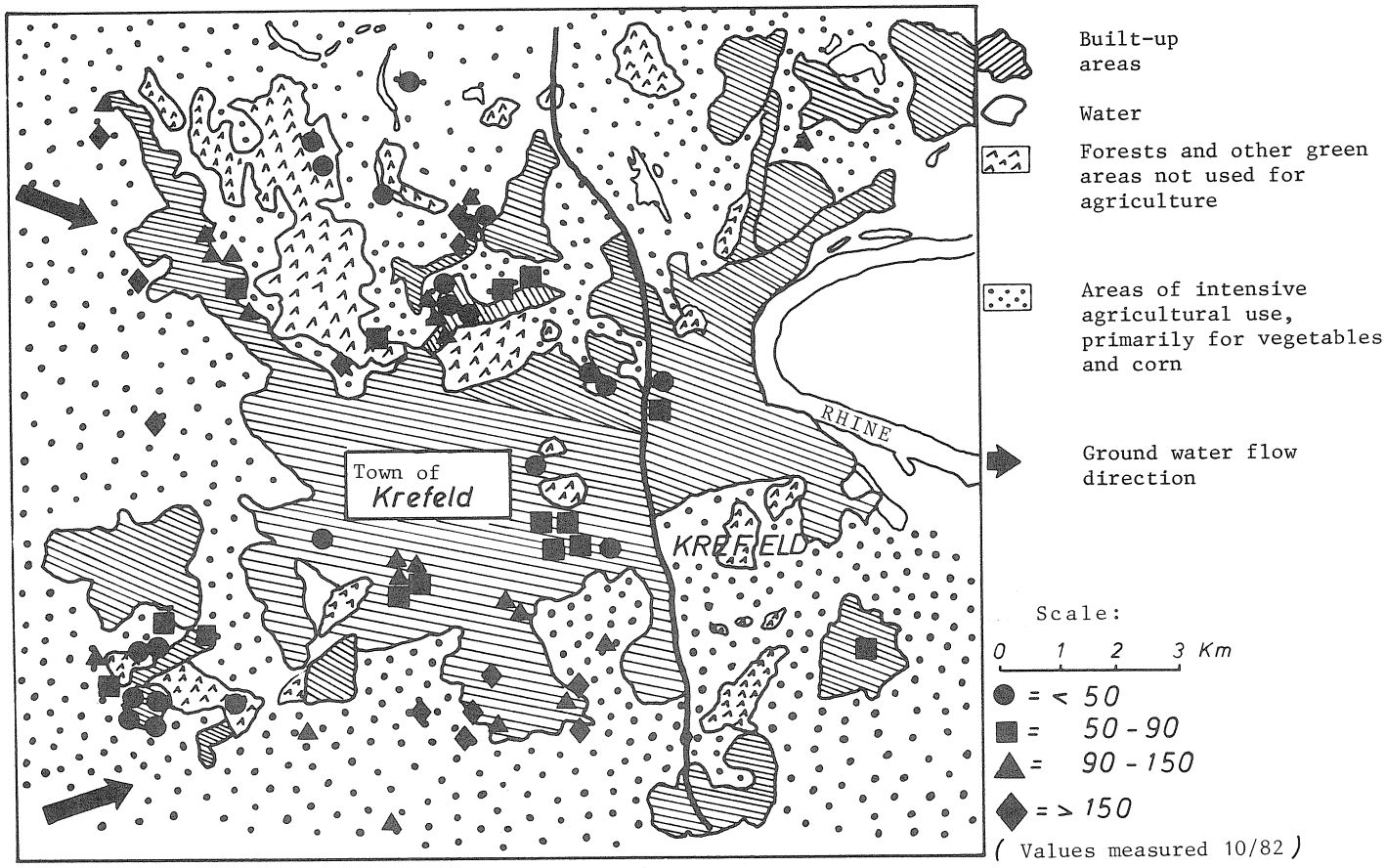

Figure 1: Nitrate contents in private wells in the environs of Krefeld (PAGEL)

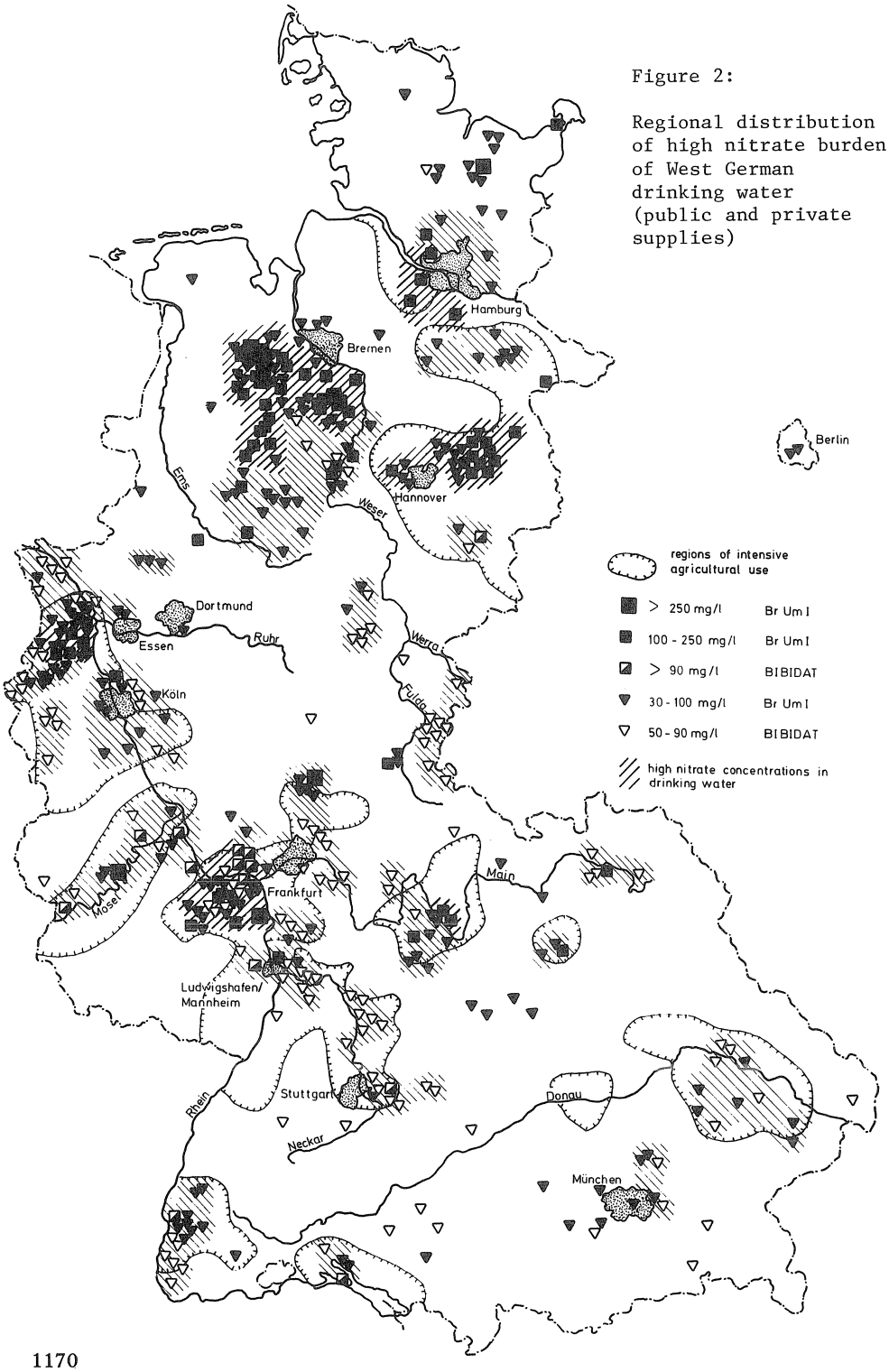

Figure 2:

Regional distribution of high nitrate burden of West German drinking water (public and private supplies)