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Regional groundwater quality monitoring in the area of Katowice Regional Water Management Council (Southern Poland)

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Abstract

Regional groundwater quality monitoring in the area of the Katowice Regional Water Management Council (KRWMC) was established in 1993. The monitoring network resulted from the execution of PHARE project known as "The Groundwater Quality Monitoring (GQM) of the Upper Vistula River Basin". The monitoring network consists of 55 sites (35 productive wells, 17 springs, 2 water galleries and 1 observation well) all of which are sampled twice a year. A broad range of groundwater quality characteristics has been measured (10 on site and 48 in the laboratory). Seven series of observations have been conducted to date. At many of the monitoring sites located in the northern, heavily-industrialised and urbanised part of the study area, there has been a progressive deterioration in the water quality, as revealed by most of the pollution indicators, but best reflected in the changes of the N-NO_3 concentrations. In fact, there has been a large increase in the N-NO_3 ion over the whole study area.

1. Introduction

The ever-growing importance of groundwater (which, very often, becomes the only and/or last source of potable water in any area) prompted the regional authorities to elaborate the principles of rational groundwater management and to promote an appropriate strategy for its protection and conservation. This task can only be successful if a well-designed and efficient monitoring programme is instituted, for a lack of reliable data on groundwater quality makes it impossible to estimate both the increase of pollution due to human impact and to institute appropriate remedial and protective measures.

In Poland, the national monitoring of the Environment consists of three types of groundwater monitoring network, referred to as the National, a regional and a local network.

The regional groundwater quality monitoring in the area of the Katowice Regional Water Management Council (KRWMC) was established in 1993. Its establishment resulted from the PHARE project "The Groundwater Quality Monitoring of the Upper Vistula River Basin" [9], [3]. This project concerned the planning and implementation of groundwater quality monitoring networks for the Kraków and Katowice sub-regions of the Upper Vistula valley. The area administered by the KRWMC extends over 7380.2 km^2 (Fig 1). This area of Upper Silesia is the largest urban-industrial agglomeration in Poland and it has been designated by the World Bank as an "area of ecological disaster". The large concentrations of industry (coal mines, Zn-Pb mines, metallurgical factories etc.) have inevitably had a huge impact on all parts of the Natural Environment in this region, including, of course, the groundwater reserves.

The basic objectives of the regional groundwater quality monitoring in the Katowice region are as follows [9]:

- the examination and permanent monitoring of the groundwater quality of the aquifers of regional importance, especially the Main Groundwater Aquifers (MGA);
- the estimation of the vulnerability of groundwater reserves to large scale pollution;
- the determination of possible trends of groundwater quality in a long-lasting cycle;
- the examination of natural and anthropogenic factors which influence water quality.

The utilisable groundwater in the area of the Katowice Regional Water Management Council occurs in Quaternary, Tertiary, Cretaceous, Triassic, Permian, Carboniferous and Devonian formations.

In terms of the basic quantity and quality criteria, as applied in Poland [2] 22 Main Groundwater Aquifers (MGAs) have been determined in the area controlled by the KRWMC. These include 9 Quaternary pore aquifers, 4 Tertiary-Cretaceous fissure pore aquifers, 1 Upper Jurassic karstic fissure aquifer, 5 Triassic karstic fissure aquifers and 2 Carboniferous fissure pore aquifers [7], [11], [1] (Fig. 1).

2. The general characteristics of the monitoring sites and principles governing their selection

As it is very expensive to set up and maintain a monitoring network, observations have been limited to those areas which are not very resistant to pollution and which are located within the Main Groundwater Aquifers. The network was adapted from an existing system of representative hydrogeological sites (wells and springs) which could be adapted to the requirements of the new scheme inexpensively [3].

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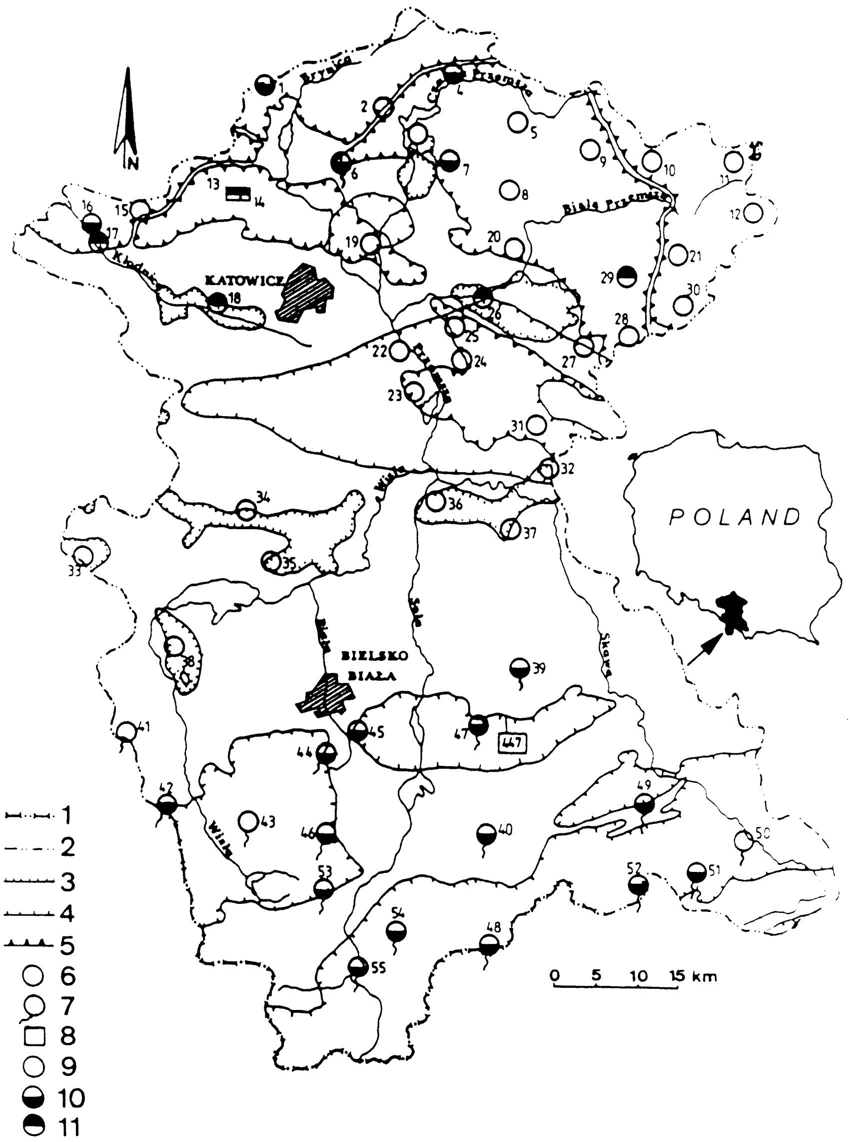

Fig. 1 Lacation of regional groundwater quality monitoring sites.

1- state boundary; 2- Katowice Regional Water Management Council boundary; Groundwater basins (MGWB): 3- porous, 4- fissure-porous, 5- karst-fissured; 6- well; 7- spring; 8- water gallery; Land use: 9- agricultural, 10- forest, 11- urban;

The sites for the regional groundwater monitoring were selected according to their representative qualities over large areas and they were not to record emission from local pollution centres.

According to these prerequirements, the selected sites had to fulfil the following terms:

- an observation site had to tap only one groundwater horizon;
- any local sources of pollution which could influence groundwater quality should be located closer than 2 km from the site;
- the materials used in the borehole construction should not themselves cause any change in the chemical composition of the groundwater sampled.

The location of the regional groundwater monitoring was such as to be representative of the local land use (agricultural, forest, urban).

Also, the degree of groundwater hazard at the various groundwater monitoring sites was to be assessed, based on the time taken for water to migrate from the surface to the aquifer studied.

The following classes of groundwater hazard are recognised [9]: AB - hazardous water, with a migration time of <25 years; C - mildly hazardous water, 25-100 years, and D - virtually non-hazardous water, >100 years.

Taking into account all of these preconditions, and after special technical adaptation, 55 sites were selected for the regional monitoring network (Figs 1 and 2).

Due to various reasons, 4 observation sites were abandoned during the course of the investigation.

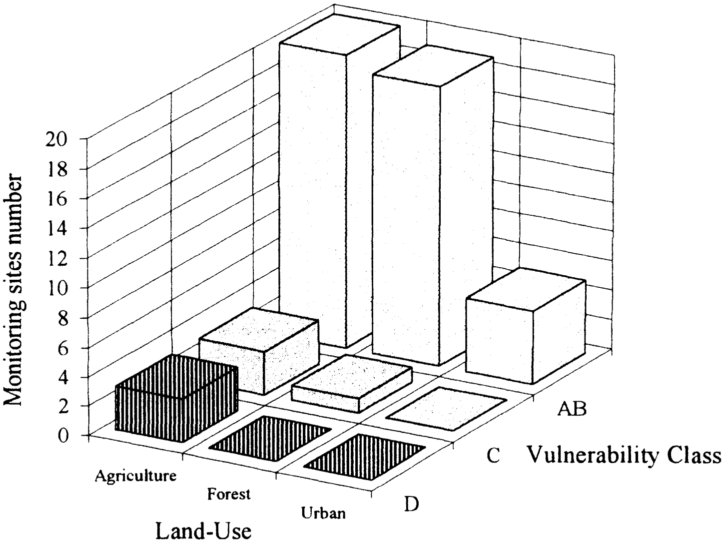

Fig. 2 Distribution of monitoring sites in the areas of different land-use and different vulnerability class.

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3. General monitoring programme

Sampling of groundwater was carried out according to the methodology prescribed by the State Inspectorate of Environmental Protection. A mobile laboratory with appropriate equipment has been used for groundwater sampling and field analysis. The following sampling methods have been used: production well discharge, a peristaltic pump (springs and water galleries), electric centrifugal pumps (in wells), flow-through chamber and filter apparatus (with an 0.45 μm filter). Ten variable parameters were measured on site (temperature, pH, Eh, colour, turbidity, specific conductance, odour, sedimentation rates of contained particles, alkalinity and acidity) and 48 characteristics of groundwater quality were also measured in the specially equipped Environmental Laboratory in Katowice.

During the investigation, a special programme of quality control, QA/QC [4] was applied in both field and laboratory programmes. In this programme, additional control samples, to the extent of 20% of the total amount, were also taken (10% doubled samples; 5% zero samples and 5% marked samples).

Within the framework of the monitoring programme, 7 series of sampling were carried out in the period 1993-1996. Sampling took place twice a year, in Spring and Autumn, though only one set of samples was taken in 1994.

Preliminary results

Generally, the water studied shows considerable variations. In the case of most pollution indicators, the values obtained lay mostly within the range of that typical for groundwater on a national scale for Poland as a whole. However, in many of the observation sites, permanent or periodic increases of concentration of some indicators (soluble substances, total hardness, Na, Ca, K, Mg, SO_4, Cl, N-NO_3, N-NO_2, Zn, Mn, Fe, phenols, chloroform,pesticides and detergents) were noted.

The concentrations of many pollutants in samples of groundwater from the water galleries of the abandoned Orzeł-Biały Pb-Zn Mine, within the Bytom Triassic Aquifer, (regional groundwater monitoring 13 and 14) differ considerably from the calculated mean values. The concentration of such substances as ammonium nitrate, (up to 10.2 mg/dm^3), potassium (up to 42 mg/dm^3), chlorides (up to 716 mg/dm^3) sulphates (up to 1508 mg/dm^3), calcium (up to 438 mg/dm^3), zinc (up to 15.6 mg/dm^3) and cadmium (up to 0.019 mg/dm^3) exceeds by several times the average values obtained from other monitoring sites.

The results obtained showed that chemical types of water differ permanently or periodically from those typical for Poland as a whole, i.e. HCO_3-Ca and HCO_3-Ca-Mg. In the area studied, several hydrochemical types of water, from simple 2-ionic to complex 5-ionic, were recognised. The following hydrochemical varieties predominated: HCO_3-SO4-Ca-Mg, HCO_3-Ca-Mg. HCO_3-Ca and HCO_3-SO_4-Ca.

One important result of the study is that there is a large and, apparently, ever-increasing concentration of sulphates in the waters sampled. In the Spring of 1993, 49% of the water sampled contained more than 20% of the sulphur ion as compared with the sum of anions; by contrast, in the Autumn of 1996, the percentage was 57 (Fig.3).

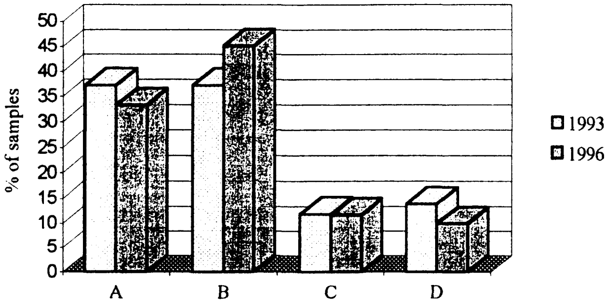

Fig. 3 Changes of chemical type of groundwater in the period of 1993-1996
A- HCO_3-Ca, HCO_3-Ca-Mg B- HCO_3-SO_4-Ca, HCO_3-SO_4-Ca-Mg
C- SO_4-HCO_3-Ca, SO_4-HCO_3-Ca-Mg D- Other (mainly multi ions)

The investigation of groundwater quality was carried out using the classification elaborated by the State Inspectorate of Environmental Protection. This recognises 4 classes of groundwater quality:

Ia - the highest quality - suitable for domestic supply without treatment;
Ib - high quality water - generally suitable for domestic supply without treatment;
II - medium quality water - slightly in excess of standards, requiring simple treatment for domestic supply;
III - low quality water, contaminated to some extent, requiring complicated treatment for domestic usage.

Analysis of the distribution of groundwater classes in individual series of sampling generally shows a slight deterioration of quality in the area of the KRWMC. The investigation also confirmed the considerable influence of the type of land use around the monitoring sites on the quality of the groundwater. Water of the worst quality is normally related to urbanisation, whereas the best is located in areas dedicated to a forestation (Fig.4). A trend towards deterioration of groundwater quality in those sites in agricultural and urban land use was also noted.

Generally, the worst quality water occurs in the Bytom Triassic Aquifer (Monitoring sites 13 and 14) and in the Quaternary aquifers.

Despite the brevity of the observational period, an attempt has been made to determine probable trends in groundwater quality changes in individual sites.

Geostatistical evaluation of the spatial variability of dynamic changes for 4 selected pollution indicators (soluble substances, Cl, SO_4, N-NO_3) was carried out using the Kriging method and the Surfer computer programme. Fig 5 shows

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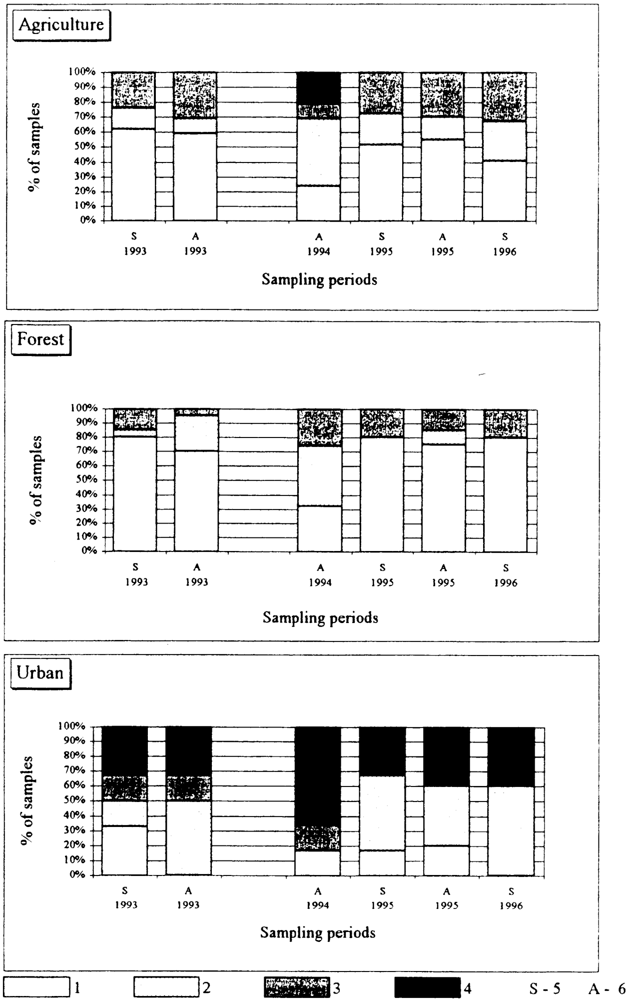

Fig.4 Groundwater quality in areas of different land-use

Groundwater quality classes: 1 - Ib high quality water (generally suitable for the drinking water supply without treatment); 2 - II medium quality water (slightly exceeding standards - demanding easy treatment); 3 - III low quality water (contamined, demanding complicated treatment); 4 - out of standards (unsuitable for the drinking water supply); Sampling periods: 5 - spring; 6 - autumn.

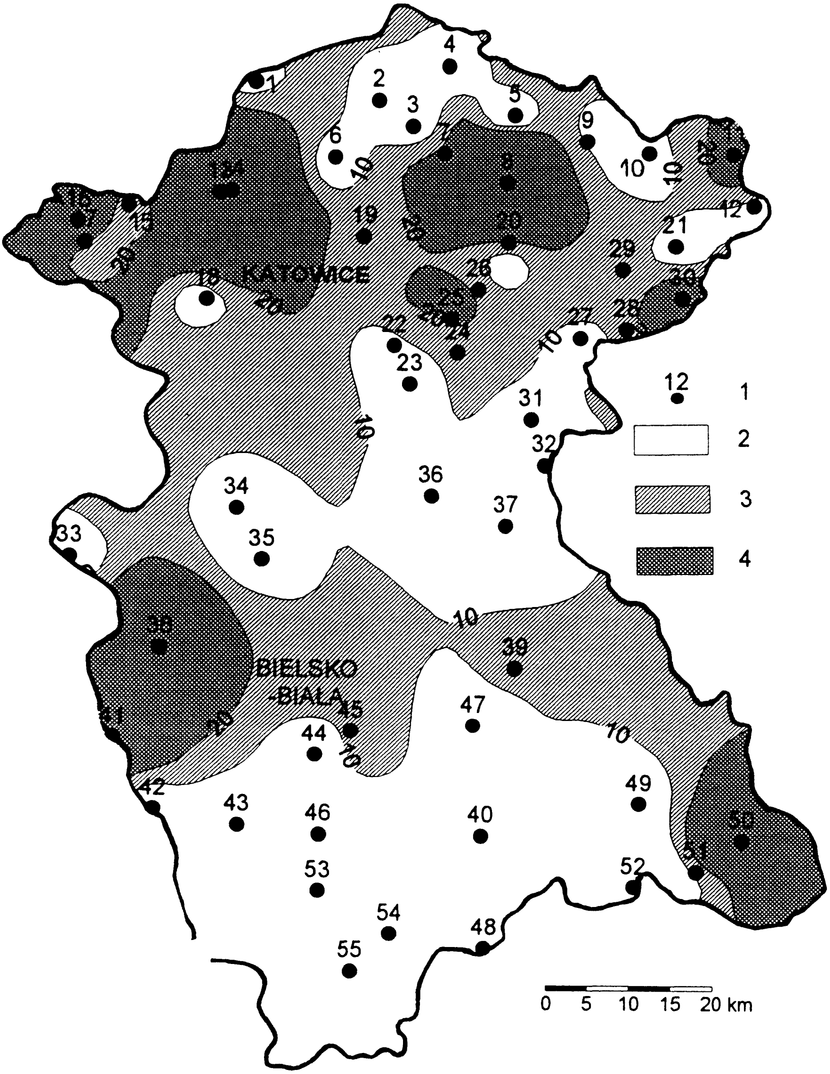

Fig. 5 Dynamics of changes of contents of N-NO_3 in groundwater in the period 1993 - 1996

1 - monitoring sites, 2 - areas of low dynamics of changes (0% - 10%), 3 - areas of medium dynamic of changes (10% - 20%), 3 - areas of high dynamics of changes (>20%)

the changes in the N-NO_3 concentration in the groundwater samples studied. In many monitoring sites, which are located mainly in the northern, heavily-urbanised and industrialised part of the study area, a trend of groundwater quality deterioration of most pollution indicators has been observed.

A preliminary analysis of these trends leads to the following conclusions:

- there is an alarming progressive deterioration of groundwater quality in what have traditionally been the largest and most valuable aquifers, those of the Triassic formations;
- there is also a gradual increase of pH in the southern part of the area governed by the KRWMC, especially in the Bielsko-Biała and Nowy Sącz Provinces (Beskidy Mountains). Concurrently, there has been a marked increase in the concentration of heavy metals, such as Cd (at 17 sites) and Pb (at 16 sites).
- the spatial distribution of dynamic changes in the amounts of four common pollution indicators (soluble substances, Cl, SO4, N-NO3) in the area governed by the KRWMC is patchy.

The marked increase in the N-NO3 ion best illustrates this increase, which is effective over practically the whole area.

Complex analysis and careful interpretation of the results of groundwater quality monitoring require a knowledge of other aspects of the Natural Environment. To integrate the results of the groundwater investigation with those of atmospheric, surface water and soils studies in the same area is, however, a very difficult task, and one which requires patient and systematic observations of the same pollution indicators [10]. This task is especially difficult where there has been an extensive anthropogenic pressure on the Environment, as is the case for a large part of the area governed by the KRWMC. In the northern, heavily-industrialised and, very often, degraded part of the study area, where different centres of pollution overlap and interact, careful interpretation of the observed groundwater quality changes require persistent complex observations of all the elements of the Natural Environment, including the aeration zone.

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