

GENERAL ASPECTS OF GROUND WATER NON-POINT POLLUTION

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ABSTRACT

The impact of non-point pollution sources on ground water quality has many forms and is manifest on regional and continental scales. With regard to the increasing extent and intensity of water pollution the need to create a centrally directed and methodically uniform system for ground water quality monitoring on the territory of the whole state and the usefulness of cartographical expression of non-point pollution on ground water protection and vulnerability maps have been emphasized. In relationship to the expressed impacts of ground water quality on man's health, the elaboration of appropriate legislative measures for ground water protection from non-point pollution sources has been recommended. The impact of polluted precipitation, high intensity of fertilizer application on arable land and rapidly increasing urbanization are considered the most dangerous sources of non-point pollution.

INTRODUCTION

Ground water is a renewable natural resource with a relatively short and shallow circulation, with close dependence on precipitation and surface water and on the influence of man whose activities qualitatively and quantitatively menace and pollute it with increasing frequency. Man has started the period of artificial transformation of the surface of our globe and, as a new element, has entered into the activity of natural forces - endogenic and exogenic, which act in opposing processes but in mutual balance. Within limited space and time, man has taken possession of natural resources exploiting them to optimize the living conditions of his race and he is multiplying rapidly. Man by his own activities may affect nature in coun-

terbalance, he may disturb the working systems created by nature, he may interfere in the activity of the biosphere, not fully knowing the long term consequences. It is true he is constructing grandiose and expensive water works which testify his intellect and his efforts to utilize water as efficiently as possible, but on the other hand he can cause it to deteriorate unknowingly or through negligence.

The topic of ground water protection within the frame of nature and environment protection are connected with growth in the negative impacts of mineral extraction, industry, transport, agriculture and urbanistic development which is going on with growing intensity in most countries of the world. Harmonization of relations between economic development and environment protection has become an extremely difficult task especially in countries with a dense population and with concentrated industrial and agricultural potentials. The measures of local ground water protection have become insufficient, and due to the increasing extent of non-point pollution sources, it is indispensable to solve ground water protection and problems connected with its pollution in regional and continental relationships.

RESULTS

Categorization of non-point ground water pollution

Ground water pollution can be categorized from different points of view. The most common divisions refer to (1) the extent of effects of pollution resources and to (2) the contaminating substances composition.

The first category of pollution is usually subdivided into two main groups, namely into point- or local pollution and non-point or regional pollution. The second category referring to the kind of contaminating substances is most frequently subdivided into chemical compounds contamination (inorganic, organic, radioactive substances and gases), vegetable and animal substances contamination (degraded organic substances, excrements, fatty acids, carbohydrates etc.), living organisms pollution (protozoa, bacteria, viruses). In other words, the pollution may be chemical, radioactive and biologic.

We also know other, less frequently used, classifications and criteria of pollution.

The category of non-point pollution includes several kinds of pollution sources differing in their origin and extent, requiring different

ways of preventive ground water protection and of the decontamination. Further on, it may be subdivided into (1) continental or global, (2) regional, (3) non-point and (4) line-pollution.

(1) The influence of precipitation on ground water quality may occur in many industrial regions of the European continent. From the point of view of the dissipation area of the polluting substances transported by the precipitation, we may speak about the extent of continental pollution with the possibility of its crossing the state borders. It is no exception for a pollution originating on the territory of one state to influence negatively the neighbouring states.

(2) The ground water pollution caused by improper application of industrial fertilizers and protective chemicals on extensive areas (thousands of km^2) of arable land may serve as an example of regional pollution.

(3) The large scale production of meat and milk with concentrations of 1,000 cows, 50,000 pigs and more at a single place leads to production of excrements which requires tens of km^2 of land for its application as fertilizers. Incorrect application technology of farm manure may cause non-point ground water pollution. Also included in this category is the ground water pollution caused by waste water and substances in the areas of town agglomerations.

(4) Ground water pollution due to losses of oil products alongside transport ways (especially highways) and due to leakage from transport pipelines (oil and gases) may serve as an example of line-pollution.

Analogically as in the classification of pollution, we may divide ground water protection according to the extent of the protected area.

It is evident that a theoretical and practical solution of the interdisciplinary problem of ground water protection and pollution requires among others the introduction of unified terminology and categorization, unification of methodology in research and evaluation etc., in a way similar to that of classical hydrogeology. The unification of terms and their meaning is a necessary condition for the elaboration of ground water protection maps.

Ground water protection and vulnerability maps

The increasing number of pollution sources requires observation of the ecological influence of polluting media on ground water and in

the form of description on ground water maps to document the horizontal and vertical extent of the vulnerability of ground water basins and aquifers against the effects of pollution.

The construction of ground water protection maps is at present in its initial stages. First maps of this kind were prepared by the end of the sixties. Since the beginning of the seventies the Bureau des Recherches Géologiques et Minières in France has been developing methodics of the construction of vulnerability maps in different scales - 1 : 1 000 000, 1 : 100 000, 1 : 50 000, 1 : 250 000 (ref.1). In the years 1968 - 1974, a larger number of ground water protection maps was edited in Czechoslovakia, namely in the scale 1 : 500 000, 18 leaves of maps 1 : 200 000 and geofactors environment maps 1 : 25 000 (ref. 2). Ground water protection maps are also being prepared in other European countries and in USA.

The ground water protection and vulnerability maps represent a very useful basis mainly for economic planning, for control of the environment etc. and are logically linked to hydrogeological maps existing in many countries.

In comparison with hydrogeological maps using an international system of symbols dating from 1970 (ref. 3) which are unified and internationally understandable, the protection and vulnerability maps are not unified, and with diversified special signs. It is no exception for a single country to use different symbols for identical phenomén.

The situation requires solution, because there is an urgent need for protection and vulnerability maps for the description of local, regional and global aspects of pollution. A team of experienced specialists at the level of respective international organisations should start constructing a model map, including a complete set of international symbols for ground water protection and vulnerability maps.

Not too long after the publication of a hydrogeological map of Europe a map of the European continent on an analogical scale should follow, documentating in a synoptical and synthetical way the important aspects of ground water protection and pollution as well as the dynamics of the relations between the natural processes of ground water creation and artificial influences caused by man's activities. The variability of pollution influences in time and space, caused by the variability of the quantity and quality of the polluting

media, requires elaboration of special methodics for the construction of protection and vulnerability maps, based on the possibility of operative and inexpensive actualization of the mentioned maps (especially on small scales) e.g. by using exchangeable transparent maps.

Ground Water Quality Monitoring

Effective preventive protection of ground water quality from the effects of non-point polluting sources, require establishing a monitoring ground water quality control program.

The optimal solution is a centrally directed and methodically unified ground water quality monitoring system covering the territory of the whole state, with a network of observation wells and selected springs, located with regard to the hydrogeological characteristics, to municipal water supply sources and to the main pollution sources. The frequency of sampling is presumed once per month, with the usual physical, chemical and biological analyses including trace elements and selected organical substances (pesticides, hydrocarbons, detergents, microorganisms). Continual registration of the contents of the selected compounds on the representative stations is desirable.

Up to the present time, only local and exceptionally regional, ground water quality monitoring programs operate in most countries. There are a global Ground Water Quality Monitoring Project and other international networks. However, the number and density of ground water points in these networks is a insufficient from the standpoint of national interests and needs.

According to available information, only the Netherlands and Nordic countries of Europe dispose of an all-state observation network for ground water quality monitoring. Sampling is carried out four times a year on the average with physical and chemical analyses and analyses of selected heavy metals and organic compounds.

The insufficient control system means that our position is in most cases a passive one, in the sense that we are usually not confronted with ground water non-point pollution until the moment of its growth to an hazard in the ecological and economical sense.

It is interesting that in the case of surface water, state quality monitoring program has been operating for many years but in the case of ground water where decontamination is undoubtedly more complicated and more expensive, there are no corresponding state programs, their

realization being considered generally for too expensive.

With regard to the different aspects of pollution sources as well as differences in the size of territory, economic potential and density of population of the countries, it will not be possible to unify the methodology of the location of sampling points in the monitoring network. In the case of most European countries, however, one control point per 1000 km² could be, at least for the beginning, sufficient.

The design of a State Ground Water Quality Monitoring Network in relation to the effects of non-point and other sources of pollutions is an integral part of the analogical network for surface water and precipitation and represents, especially for economically developed and densely populated states, an important, through financially demanding, program. Its successful realization will depend on the optimalization of the methods of the network design, sampling methods unification, solution of connected hydrochemical tasks including evaluation and interpretation of the collected data and information.

Non-point pollution impact on man's health

The high proportion of ground water in the water supply for the population (e.g. in most European countries ground water supply amounts to 45% of the total water supply) is an important aspect of ground water protection even from the sanitary standpoint.

The ground water standard is a guarantee that man is not offered water of unsuitable quality. But in many areas of the world man is supplied from his own water sources where no ground water quality control is carried out at all or irregularly only and with a long interval.

Changes in water quality are either sudden and enormous and their influence on man is immediate (use of water with temporary high biological and chemical pollution) or water has been polluted only slightly but permanently and of course with possible long term impact on man's health.

The example of increasing nitrate contents in ground water can be used to demonstrate the variability of impacts of chemical components on man's health.

The often quoted methemoglobinemia as a consequence of the sudden use of enormous quantity of nitrates may appear only in artificially

nourished sucklings where it must be diagnosed and cured in time otherwise it may lead to death. Methemoglobinemia appears at older children and at adults exceptionally only.

At the same time, physicians are studying the danger of the long term use of slightly elevated nitrate contents for the organisms of adults. The compounds of nitrates and nitrites with amines (nitrosamines) increase the danger of carcinogenic impacts first of all on the digestive tract, urination tract and unfavourably influence even the cardiovascular system in the sense of extreme artery dilation.

Standards of most countries permit 50 mg/l NO_3 in drinking water but at the same time they state that a quantity up to 100 mg/l is still admissible. This admittance is based on the assumption that no acute sickness can occur and that no long term sickness has been unanimously proved. But it has not been proved mainly for the reason that no long term medical examination are available.

In drinking water standards primarily observed are the components, selected for their toxicity, persistence and bioaccumulation. Less attention has been paid to other components. There is lack of interdisciplinary medical - hydrochemical - hydrogeological studies of long term impacts of chemical and biological ground water components of low and of elevated contents on the human organism. These studies will prove a closer connection between ground water quality and man's health than has been believed up to now and they will provoke respective modification for drinking water standards.

Legislation concerning ground water protection

Legislation on ground water protection may be divided into three groups: up to present, no laws have been enacted (1), laws have been enacted incompletely and therefore not fully operational (2), laws have been enacted in full and are operational (3).

Most countries may be included in the second group, with legislation and adequate directives, acts and laws for ground water protection in a general sense.

From the legislative standpoint let us judge the state of ground water protection from the impact of non-point pollution which requires not only protection of water supply sources but also protection of extensive parts of aquifers, their recharge areas etc. Up to now,

the countries with valid acts specially orientated to ground water protection from non-point pollution by excessive fertilizer application have been an exception only. In Europe there are areas where NO_3 contents in ground water have exceeded 50 mg/l and there are available proofs enough to show it is due to excessive arable land fertilization. With few exceptions, it is not possible to find the real trespasser in the sense of the law. How can one prove without any direct control who of hundreds of farmers and dozens of agricultural cooperatives operating on some millions of hectares really fertilized excessively and uselessly and who polluted the ground water. Unfortunately in this case, ground water pollution, above all by nitrates, is not considered to be pollution by negligence. The farmer usually does not take into account the consequences of his own activity. From his standpoint he is not doing anything illegal by employing uncontrolled amount of fertilizers as the laws of no countries have so far not stated obligatorily any limits to fertilizer application in relationship to ground water protection.

Another important legislation problem is the multigrade water source protection, with protected areas covering some tens of square km, where man's limited economic activity is required.

It is evident that the legislation of many countries does not get to deal with the consequences of non-point ground water pollution and protection.

Perspectively dangerous pollution types

Having in mind the extent of pollution, prognoses on its growth and sanitary impacts, (1) continental pollution by precipitation, (2) regional pollution by fertilizer application, (3) non-point pollution from urban areas, seem to be of the highest importance from the hydrogeological and ecological standpoints.

Impact of precipitation on ground water quality

Energetic problems in countries where sufficient coal reserves are available lead to an increase in their use. Production of energy from coal jointly with other industrial branches lead to the antropogenic pollution of atmosphere by gaseous emissions and by flue dust. Under certain conditions there may be a direct or an indirect impact of

precipitation water on ground water quality. From the standpoint of the extent of pollutants dispersion and of the possibility of impact on ground water quality, we see here a non-point pollution of continental extent.

Some microelements determined in precipitation water (Pb, Zn, As, Ni, V etc.) have been found as a manifestation of an antropogennic impact even in ground water. In precipitation water organic materials are also present (chloride hydrocarbons, cyclic aromates etc.).

Investigation of organic hydrocarbon in unpolluted ground water in Bohemia (ref.4) has proved that the natural background of hydrocarbons is 0.035 mg/l. Due to analyses these hydrocarbons are mostly aromates (toluen, xylens) and alkenes $C_6 - C_{23}$ which testify to the natural and also the antropogennic origin of hydrocarbons. A similar composition of hydrocarbons has been found in corresponding precipitation water, too.

The impact of anorganic components of precipitation water on ground water quality has been also studied. On the territory of Bohemia e.g. the total mineralization of precipitation water is from 30 to 250 mg/l. Chemical type of precipitation water is $Mg - SO_4$ to $Ca - Mg - SO_4$ with low pH values (6 - 6.5). By migration through the soil and weathered rock layer, the sulphate water type changes into a bicarbonate type. At the same time, the sulphates accelerate the nitrate wash-out from the soil layer into the ground water and act as one of the nitrate growth sources in ground water on the territory of Bohemia. Together with other impacts on ground water quality (fertilization) and with the effect of climatic conditions, areas of an increased soil saltiness may arise. Such changes in the soil fertility may become a serious economic problem even in European conditions.

Wide international cooperation required to study the impact of precipitation water on ground water quality. The link-up of programs for long term monitoring of precipitation and ground water, including analysis of emission and dust in the atmosphere, construction of lyzimetric stations in the representative hydrogeological basins for observation of the interactions: precipitation - soil - unsaturated zone - ground water, would be very useful.

Impact of fertilizers on ground water quality

The efforts of states to reach maximum self-efficiency in cereal production, which is a strategical raw material in the economical and political sense, can be seen above all in the increasing intensity of fertilizer application with the aim to raise hectare yields.

In the West- and Central European countries having no soil reserves, with a small percentage of arable land per one inhabitant (0.75 - 0.25 ha), with a high fertilization intensity, the consequences of cereal production intensification are being shown from the beginning of the sixties. Mass fertilizer application, especially nitrogen fertilizer to arable soil, influenced the soil ecosystem to different degrees during two decades (1960 - 1980). The efficiency of the soil as a biological filter decreased with subsequent negative influences on ground water quality. The problem of nitrogen pollution is mainly visible in areas with a smaller thickness of the unsaturated zone and ground water level just below surface and with absence or small thickness of the covering protective layer of low permeability. Over 40 mg/l of nitrate in the ground water are reported in these areas. From the data of various European countries we may see that nitrate contents in ground water in areas of arable land are on average from 12 to 25 mg/l with an increase of 1 - 2 mg/l a year. This means that in next future the nitrate content of ground water, in a significant part of arable land of west- and central Europe, will reach a level of 50 mg/l or more (without taking into consideration any further fertilization intensification which is, of course, steadily increasing).

Thus we are witnessing an anonymous, hidden, non-point and long term ground water pollution which in some areas may change into an ecological hazard for masses of subsurface water, the restitution of which will either not be technically solvable at all, or only at the price of long-term social and economic consequences. Of course, nitrates are not the only manifestation of fertilizers on ground water quality. The increase in content of heavy metals or fluor (from phosphor fertilizers) etc. is a warning signal.

Only a few countries are giving systematic attention to the impact of agricultural activities on ground water quality. Investigation on extensive experimental agricultural fields to study the migration and interaction of nitrates in vegetation cover - soil - ground water - rock system in natural conditions, together with results of the

mathematical modeling of these processes, are desirable. In the modelling of this type of non-point pollutions, the main problems consist in the difficulty in stating the chemical, biological and microbial reactions velocities, in the lack of precisely stated long-term data about chemical and biological ground water variation in time and space and the selfpurification capacity of the ground water and rock mass etc. Prognoses are complicated also by the fact that in significant parts of the continents exist areas on which the natural background of the qualitative ground water composition has not been stated.

Up to now, there has been a lack of information on the impact of the unsaturated zone on contaminant degradation and zonality, on chemical and biological sorption and desorption of agrochemicals, on the significance of the edaphon, on the impact of quantity, sorts and manner of application and of the time order of employing fertilizers on ground water quality etc.

We cannot expect, farmers to give preference to observing ground water protection over their own agricultural interests. Water managers, hydrogeologists and ecologists themselves have to take the initiative in solving such a demanding task which may be simply formulated as "Optimum creation of digestible albumens from agricultural soil with minimum impact on ground water quality".

Ground water non-point pollution in urban areas

The world-wide trend of expanding urban areas is increasing and according to various sources of information they will have covered about 15% of the continents within the next twenty years. Rapid and sometimes even uncontrolled growth of cities is not always accompanied by the relevant protection of the environment.

Ground water pollution in urban areas occurs first of all due to the insufficient extent of urban sewage systems, due to industry and local stockyards etc. Some part of the pipe lines for different purposes causes higher temperature of ground water with corresponding hydrochemical processes. Ground water in domestic wells in the suburban areas is mostly polluted chemically and biologically.

In United Kingdom 90% of the population is said to be using urban sewage systems and 80% of these systems have secondary treatment. This signifies a world standard which unfortunately has been reach-

ed by a very few countries only.

Urban pollution goes beyond the built-up areas. Unsuitably located stockyards, especially older ones, ignorance of stockyard management, incorrect tipping of toxic waste etc. are causes of the ground water pollution up to hundreds of meters from the stockyard field. Rectification has been already started or is being planned (controlled and special stockyards for toxic, oil and other materials, closed cycles of industry waste water).

In the future, urban area can exceptionally only be considered as sanitarily irreproachable for ground water captation for drinking purposes. But it is necessary to solve ground water protection even beyond this area, in the environs of towns, which act as nonpoint pollution sources with enormous qualitative and quantitative heterogeneity.

Underground walls and other underground artificial barriers, underground and open drains etc. as technical works of an active and passive ground water protection, will be desirable to protect ground water sources in the proximity of towns.

The location of towns and water sources cannot be for technical and natural reasons changed. Securing their coexistence and with regard to the complexity of the influence of urbanization on ground water quality inside and outside the urban area, is a highly demanding task the study of which requires our full attention.

Conclusion

The problem of ground water non-point pollution is urgent, above all in the European continent where there are countries of developed industry and agriculture and of dense population which have high economic and consumption demands, with the corresponding high level of municipal water supply from ground water sources.

The ground water protection must not be taken as a single problem that is to be understood at the very moment of its origin. The ground water protection is a long-term and ruled process in the ecologic, economic and social sense. The transfer of the ground water protection into the sphere of prevention and the working out methods of prophylactic ground water protection, including a consequent control system are an actual world-wide task.

With regard to practical experience and investigations of developed

countries, it is within the power of Governments of developing countries to carry out as soon as possible the preventive and legislative measures so that the non-point pollution would not turn into an important economic and social problem.

Ground water pollution is a world wide problem. Given effective international cooperation and a comprehensively elaborated and consistently carried out program of ground water protection, it is within man's power to limit gradually the pollution of ground water resources, which are indispensable for man's life.

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