

A PROPOSAL FOR THE DIMENSIONS OF PROTECTION AREAS

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ABSTRACT

Although the only way of safeguarding the quality of the groundwater is to prevent any risk of pollution in the whole recharge area, it is mostly impossible to maintain that principle for practical and social reasons. Therefore many different systems for the protection of watersupply-areas are applied, which are based on technical and on socio-economic and administrative factors.

From a technical point of view a protection system has to depend on the hydrogeological properties of the aquifer. In this respect an important distinction can be made between porous-permeable (mostly unconsolidated) aquifers and fissured and karstic (consolidated) aquifers, especially in relation to the flow velocity of the groundwater. Moreover, it is appropriate to distinguish between a pollution with persistent compounds and a pollution of a degradable nature, which may lead to a zoning within a protection area.

For both types of aquifer a protection zone around the well field is established which should guarantee a delay-time of at least 50-60 days before the groundwater in the aquifer is pumped; that time should be sufficient to break down disease germs.

Much larger protection areas are necessary to protect against compounds which are not or hardly degradable; to the question of the size of these areas considerations of safe and continuous water supply are relevant.

For porous-permeable aquifers a protection area is proposed which has to guarantee a delay of the groundwater in the aquifer of 25 years; an internal zoning based on a delay of 10 years may be appropriate. As the flow velocity of the groundwater in fissured and karstic rocks is very high, and so the protection areas would be of an enormous extent, this principle may be impractical. In that case the protection area should be restricted to a distance of 2 kilometers from the wells; this distance has been successfully applied in Germany for a long time.

Regulations in the different protection areas can be applied in order to restrict the presence of hardly degradable substances in the zones of 10 and 25 years and of 60 days of delay. In the inner zone of 60 days an additional restriction on the introduction of disease germs is necessary.

## INTRODUCTION

At present much attention and much money is paid to rather extreme cases of ground-water pollution, mostly caused by thoughtless dumping of chemical wastes and by leakage of transport and storage of chemicals and oil. A considerable number of cases, known in The Netherlands, occur in recharge areas of water catchments for public water supply. However, apart from the pollution with these chemicals, which are often endangering to health, pollution with less harmful substances also occurs. The drawback of this type of pollution is that it is diffuse and occurs in many varieties in the environment; e.g. the examples of the decline of the groundwater quality as a result of agriculture or of the influence of air pollution are countless. In relation to the protection of groundwater quality this kind of pollution is very difficult to control and to regulate.

It is quite correct that case histories and research results are described again and again; unfortunately, it is practically impossible to collect all desired data; therefore, the descriptions must remain incomplete. Nevertheless, for the exchange of experience and for evaluation these reports are necessary as eye-openers.

Many case histories relate to affairs in which people, whether consciously or not, acted carelessly. Today it is our task to repair those mistakes, and especially to prevent pollution of groundwater. Prevention is of older origin than sanitation, in view of the fact that, in many countries, of old, severe legislation concerning the contamination of water wells, used for drinking water, exists. A study on the history of the protection of the quality of groundwater in relation to legislation in the different countries is worthwhile, and also necessary in order to arrive at uniform guidelines and legislation. The subject is so extensive that another specialised symposium would be necessary; in this symposium we have to restrict ourselves to the hydrogeological aspects of the protection of groundwater, and especially of the water that is destined for drinking water supply.

Having thus limited the topic of this paper one could simply end it by stating that the only way to safeguard the quality of groundwater is by forbidding any possible source of pollution within the recharge area around a water-catchment. From that area any addition of material to the groundwater will finally reach the wells in some form. It is clear that this ideal protection is impossible, and one will have to look for a second-best solution. According to the legislative, socio-economic and hydrogeological situation, many countries have developed their own protection system. To go into that subject would also require another symposium; a second restriction to this theme is the restriction to the second-best solution which is being introduced in the Netherlands at this moment, and which may be useful to other countries.

#### Hydrogeological situation in The Netherlands

Before giving an outline of the protection system, it is useful to emphasize the specific hydrogeological conditions in The Netherlands. Since the beginning of the

Tertiary age the greater part of the country has been a continuously sinking basin, in which sedimentation of marine and fluviatile sands and clays took place. There was little tectonic movement (faulting). During the pleistocene ice ages some formations have been pushed vertically by the ice; the greater part of the sediments are layered horizontally. The topography is rather flat or sometimes hilly. Only in the very south and east of the country one will find consolidated rocks (sand- and limestone). In comparison to many other countries one can speak of rather uniform, horizontally layered aquifers of unconsolidated sands and clays. In these aquifers there is a laminar flow of groundwater with velocities of 10-100 m per year.

Another important feature is the rather high level of the groundwater, which varies over large areas between 0-2 m below surface.

Of course, the picture has been oversimplified and the situation is much more complicated; details are important when talking on protection problems.

Another important difference compared with many other countries is that the production of drinking water is concentrated; there are about 110 watersupply companies with 240 well fields from which the yield is over 700 millions of m<sup>3</sup>. Private wells for drinking water are very rare, as practically all housing is piped.

#### Some starting points for protection

To achieve a practical system for protection areas around water catchments, some starting points with an eye to watersupply and practice may be shortly mentioned:

- 1 When the whole recharge area is not protected, one has to be content with a second-best solution. In that case certain risks for the groundwaterquality will have to be accepted.
- 2 Because of the properties, quantity and place of a possible emission of a pollutant, a zoning within the protection area is desirable.
- 3 An increase of the catchment or future catchment areas have to be taken into account where a difference can be made between short term (10 years) and long term (25-30 years) realisation of production.
- 4 Generally speaking one cannot count in advance on elimination of a pollutant by purification processes in the underground; nor may one count on the possibility of decay and dilution during the passage through the soil.
- 5 Protection of groundwater quality should be strongly preventive; sanitation afterwards is a very complicated affair, both technically, administratively and financially.
- 6 Technical guidelines for the protection of groundwater quality should be used in the weighing of interests.

Another point of view of the regulations within the protection areas is that no standards as to the quality of the groundwater exist. It has to be suitable for the production of drinking water by means of the usually rather simple purification processes; this suitability should not be affected. Negative influences in that suitability

lity may come from health affecting compounds (toxic, carcinogenic, mutagenic substances, pathogenic bacteria and viruses and radioactive materials) and substances which impair taste, odour and color or may cause anaerobia or corrosivity, hardness and temperature of the groundwater. A rather detailed survey of these compounds has been given in the Directive of the European Community on the protection of groundwater against pollution by the introduction of certain dangerous compounds (ref. 1). The list of chemicals is rather long as is the list of activities by which the compounds may be released, and which is given by the German Association of Gas- and Waterworks (DVGW, ref 2).

Advanced methods of analysis have proved that many micro-parameters occur in groundwater, their presence was unexpected and the usual methods of analysis are unsuitable to detect them. Further advancement in methods of chemical and toxicological analysis may raise new problems to the protection of the quality of groundwater.

#### Protection zones

As stated earlier during this symposium many processes in the soil may play a role in dilution, decay or other attenuation processes. From the point of view of safeguarding the public water supply, however, the results of those processes cannot be relied upon. Nevertheless, it is useful to distinguish between a protection against compounds and organisms which degrade relatively easily in the soil (e.g. germs) and chemical compounds which do not or hardly degrade. This difference provides a handle for zoning within protection areas.

In hydrogeological view a distinction has to be made between porous-permeable, mostly unconsolidated aquifers and consolidated aquifers of a fissured or karstic character. The most important reasons for this distinction are the differences in flow velocity, in the flow system (laminar/turbulent) and in the degree of purification in the pores or the absence of the last mentioned processes.

Although the differences in flow system in fissured rocks and in karstic rocks are important, they are less important in the description of the protection system. In case of a fatal threat to a water catchment, there must be enough time to eliminate the source of pollution and its consequences or, in the worst case, to find and to realise an alternative source for drinking water. This has led to the development of a system of protecting the groundwater by the introduction of protection zones, which guarantee a certain delay time for reparation activities. It has repeatedly been said that this is a second-best solution.

Historically the first protection of groundwater used for drinking water supply is directed against a pollution with pathogenic germs; the first directives on protection give a necessary delay time of 50-60 days before the groundwater is recovered. This delay should in general be sufficient to achieve a decay of the germs, so that they have lost their pathogenic properties. This required delay is being reviewed at present with a special eye on the survival of viruses; perhaps a longer delay time of

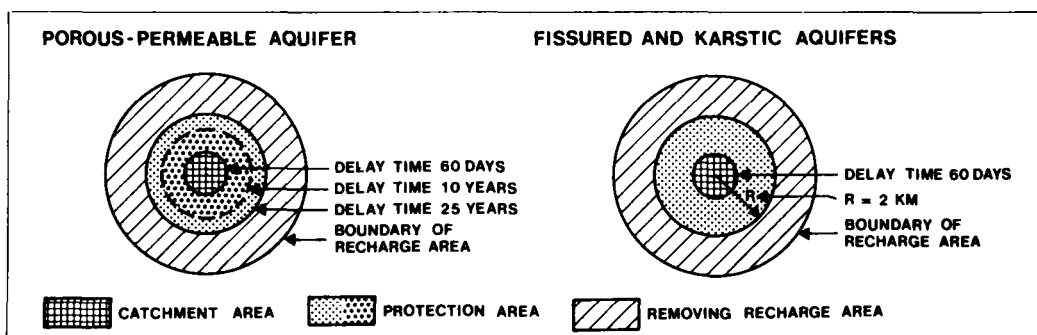
e.g. 100 days or 1 year will be necessary. It is clear that within these 50 a 60 days there is no possibility for any repair or sanitation; this area should be well protected and therefore, it has to be owned by the watersupply company. To indicate the strong link to watersupply this zone of 50-60 days is called the catchment area; in the Dutch situation it will reach from 10 to 150 m from the wells.

In case of severe pollution of a persistent character within the recharge area, an attempt is made to repair the damage. In many cases this repair will take a long time and often will not be perfect, so the outlook is that the wells will be affected. It should be monitored what is exactly happening in order to be conclusive on the sanitation measures, which may include the development of new purification processes or even the replacement of the catchment. The Act on Water Supply obliges the Water Works to provide water of good quality and in sufficient quantity, irrespective of origin. For the sake of the continuity of watersupply and to exclude risks to public health, at least a delay of the groundwater in the aquifer of 10 years is needed, which results in a 10-year protection zone.

Because in many cases 10 years will not be sufficient to guarantee continuity of safe watersupply a 25 year protection zone will be necessary. The protection zones of 10 and 25 years together are called the protection area; in the Dutch situation the different zones extend about 800, resp. 1200 m from the wells.

In karstic and fissured aquifers the flow velocity of the groundwater may be very high; in the dutch situation the velocity range is 10-100 m/year, whilst in karstic regions velocities of some kilometers per day are known. It is clear that the principle of minimal delay times for protection areas in case of high flow velocities will lead to very large protection areas, which are impossible to realise and to maintain. In the case of fast flow, nearly always in consolidated, fissured or karstic aquifers the protection will have to be restricted further. In analogy with the German directives on protection (ref. 2) the establishment of a catchment area with a delay of 50-60 days is proposed while the protection area could be restricted to a distance of 2 kilometers from the wells. This German system is also a second-best solution, but has proved to be useful for more than thirty years.

For both hydrogeologic systems the different protection zones are given in figure 1.

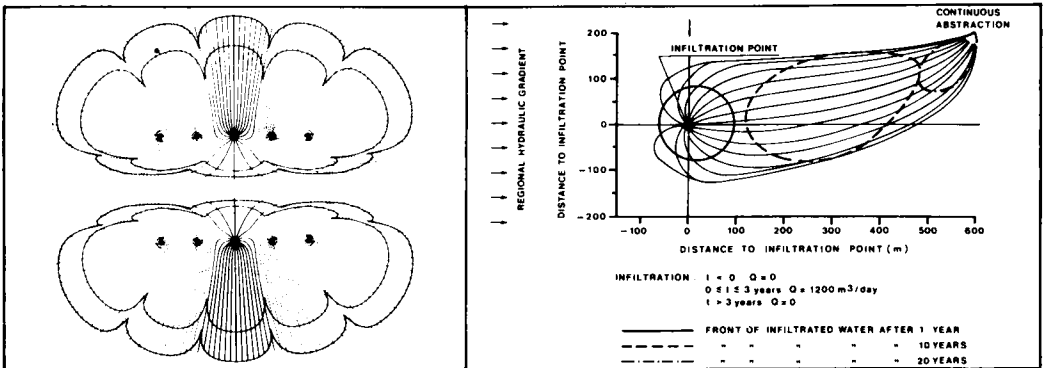


<p><b>CATCHMENT AREA</b></p> <p>60 DAYS AND ≥ 30 m</p>	<p><b>PROTECTION AREA</b></p> <p>10- AND 25 YEARS DELAY-TIME OR 2 KILOMETER</p>	<p><b>REMAINING RECHARGE AREA</b></p>
<p><b>PROTECTION AGAINST PATHOGENIC BACTERIA AND VIRUSES, AND AGAINST CHEMICAL POLLUTION SOURCES</b></p>	<p><b>PROTECTION AGAINST HARDLY-DEGRADABLE CHEMICALS</b></p>	<p><b>RULES OF ACT ON SOIL AND GROUNDWATER PROTECTION</b></p>
<p>ONLY ACTIVITIES IN RELATION TO WATER-SUPPLY ARE ADMISSIBLE</p>	<p>AS A RULE ARE NOT ADMISSABLE E.G.:</p> <ul style="list-style-type: none"> <li>- TRANSPORT AND STORAGE OF DANGEROUS GOODS</li> <li>- INDUSTRIES</li> <li>- WASTE-SITES</li> <li>- BUILDING</li> <li>- MILITARY ACTIVITIES</li> <li>- INTENSIVE AGRICULTURE AND CATTLE-BREEDING</li> <li>- GROUND-, SAND- OR LIMESTONEPITS</li> <li>- WASTE WATER</li> </ul>	

Figure 2 refers to restrictions on the activities within the protection zones. From the point of view of legislation it will often be preferable to establish a system of prohibitions with a possibility of exemption. In technical view one can give an enumeration of hazardous activities, which in general are not allowed in protection zones; in this way the risk can be estimated. It must be said that especially in the protection areas of fissured and karstic rocks utmost prudence must be exercised, because of the fact that the groundwater mostly does not flow through the matrix, so that attenuation processes will not be successful.

Advantages of the proposal of the above given protection system, including its starting points, is the possibility of a realistic weighing of interest of water supply and other public interests; besides, in the calculation of zones of a certain minimum delay time all geohydrologic features can be taken into account.

Some results of hydrological calculations are given in figures 3 and 4, which speak for themselves.



With the principle of delaytimes it can be said that a lot of attenuation processes in the underground are time dependent; uptill today little is known of the exact behaviour of chemicals. In future, when more will be known, facts about processes and required delay times may be considered jointly.

It is superfluous to say that the protection of the quality of groundwater, destined for public water supply, includes a lot of disciplines, among which hydrogeology plays a leading role, next to chemistry, physics and microbiology. A combination of these disciplines in tackling a problem will lead to an analysis of the risk for the quality of the groundwater and the water supply. Thereafter, a political decision on conflicting interests and within the possibilities of the acting legislation has to be made. It is a premise that the whole system leads to a feasible and practical solution.

#### REFERENCES

- 1 European Community; Directive on the protection of groundwater against pollution caused by the discharge of certain dangerous substances (EC, 26th January 1980, publ. L20/43-48).
- 2 German Association of Gas- and Water Supply Companies; Directives for the protection areas for water supply (part I, Groundwater catchment areas) (in German) DVGW-Arbeitsblatt W101, 1975). See also in: D.K. Todd; Groundwater pollution in Europe, a conference summary. General Electric Company, Tempo, Santa Barbara Cal. GE73 TMP-1, (pp. 60-77), 1973.
- 3 Committee on Protection Areas; Directives and recommendations for the protection of groundwater catchment areas. National Institute for Water Supply, Voorburg, The Netherlands, December 1980) (in Dutch).