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INTRODUCTION

The WHO Regional Office for Europe, in association with the Water Research Centre, United Kingdom (a WHO Collaborating Centre for Water and Waste Disposal), convened a meeting of the Working Group on Rural Water Supplies in the European Region as part of its International Drinking Water Supply and Sanitation Decade (IDWSSD) programme. The meeting was held from 1 to 5 November 1982 in Stevenage, United Kingdom.

The Working Group was complementary to the Working Group on Appropriate Technology for Wastewater Treatment Systems for Small Rural Communities that met in Lyon, France from 7 to 11 June 1982.

Dr J. Cuthbert, Director of Process Engineering at the Stevenage Laboratory of the Water Research Centre welcomed the participants on behalf of the Centre. Dr G. Watters, Regional Officer for International Water Decade, gave an introductory address on behalf of the Regional Director. Mr R.W. Fraser was elected Chairman, Dr P. Benedek Vice-Chairman and Mr M.J. Stiff Rapporteur. The list of participants is given in Annex 8.

The scope and purpose was to consider the current technology applied to small water supply systems in Europe, particularly in isolated rural communities. As well as present approaches and new technology, other related aspects such as surveillance, maintenance and the inclusion of chemicals were discussed. The aim of the meeting was to produce guidelines to assist Member States of the European Region in selecting appropriate technology to cater for different water sources under various social, cultural, topographic and climatic conditions.

For part of the meeting the Working Group divided into three subgroups to discuss:

- the technology of water treatment and disinfection for all types of source and distribution system;

- the technology of water supplies, other than treatment and disinfection, particularly source selection and protection and distribution, for all degrees of treatment and forms of distribution;

- appropriate organization, administration, surveillance and personnel training.

Each subgroup was charged with making recommendations in its particular area of competence, both for the benefit of Member States and for further international action. The membership of the subgroups is given in Annex 7.

RURAL WATER SUPPLIES IN THE EUROPEAN REGION TODAY

A questionnaire had been sent to a representative selection of countries before the meeting to determine the state of rural water supplies in the European Region and data were obtained from six countries. Members of the Working Group had also prepared written statements on rural water supplies in their respective countries. Twelve countries were represented, five of which had also provided data for the questionnaire. Thus information on 13 countries was available and what follows is a picture of rural water supplies in the European Region based on the information provided by these countries.

Definition

It is clear that there is currently no precise definition of a European rural community. Each country has its own definition and this depends on its state of development. There are a number of ways in which a rural community might be defined, according to size, remoteness from amenities, per capita income, or whether the economy is based on agriculture. In general, however, size is taken as the criterion and some examples show the differences that exist both among countries and between definition and practice within countries.

In Romania, many villages have become urbanized, with their economies more dependent on industrial enterprises and the bulk of the rural population living in communities of between 2000 and 10 000 inhabitants. In Turkey, villages with a population of less than 3000 are classified as rural, but in practice 86% have populations of less than 1000. In France, although communities of less than 2000 are regarded as rural, the average population of rural communities is about 600. Likewise, in the Socialist Republic of Macedonia,[a] the average population of villages is 530. In Scotland,[b] the bulk of the rural population lives in communities of less than 500, very often less than 100. A village of more than 1000 inhabitants would have many urban characteristics.

Because of the lack of a precise definition the subgroup on appropriate organizational structures addressed itself to this problem (see p. 30).

The scope of the problem

The supply of potable water to rural communities is of two kinds. There are public supplies and there are private supplies serving individual dwellings, farmsteads and the like. The problems associated with the two kinds are quite distinct. The questionnaire sought information on the population served by rural supplies. Most replies related to public supplies and are summarized in Table 1. Although the questionnaire asked for data as

Table 1. A cross-section of the rural water supplies in the European Region

Country	Rural population served by public water supplies (millions)	Rural population served by individual systems (millions)	Total population of country (millions)
Hungary	—	2	11
Norway	0.8	—	4
Portugal	1.6	4	10
Romania	1.5	9.5	22
Spain	4	—	36
Turkey	16	4	45
United Kingdom	0.5	2	56
Yugoslavia (Macedonia)	0.6	0.3	2

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[a] One of the republics that make up the Socialist Federal Republic of Yugoslavia.

[b] In the United Kingdom, the organizational structures of the water industries in England and Wales, in Scotland and in Northern Ireland are quite distinct and separate.

percentages, these have been converted to actual numbers to show the scale of the situation in the different countries. The rural population not served by public supplies must be served by individual systems and these numbers are also shown in Table 1. Data made available at the meeting for Romania and Macedonia have been added.

If the figures given in Table 1 are assumed to represent a true cross-section of the European Region, nearly 30% of the population live in rural communities and only half of the rural population is served by public water supplies. Almost the same number obtain their drinking-water from individual systems.

Mode of distribution

There is a general trend throughout the Region for water to be supplied to houses through pipes. For example, 65% of the rural population of Macedonia now has a piped supply compared with only 20% some 20 years ago. There is, however, a practical limit to the population that can be supplied in this way. In Poland, where the rural population is very scattered and will remain so for the foreseeable future, no change is anticipated in the present situation, where individual wells are the predominant method of water supply. In the north of Spain, where communities are also widely dispersed, it may likewise never be possible to provide a piped supply to every household. In the United Kingdom, while it is the legal right of every household to be provided with a piped water supply, that right is limited to provision at reasonable cost.

Without saying precisely how it will be effected, it is the stated intention of every country that the entire population shall eventually receive a safe and adequate supply of drinking-water. The problem can be divided into two separate issues. On the one hand, how do the authorities ensure the safety and sufficiency of water delivered by individual systems that will continue indefinitely and, on the other, how shall that part of the rural population that lives in communities be properly served?

In a number of countries, the first stage in the provision of an adequate community supply is the provision of public fountains or standpipes fed from a water-main. This pertains, for example, in Portugal and Romania, but it is seen very much as an interim measure, with pipes being connected to houses as circumstances permit. In Turkey, the fountain supply may remain where only low-yielding sources are available, where housing is of a poor standard, or where communities are very scattered.

Individual systems

Very small, isolated communities and single dwellings or farmsteads are not likely to be served by distribution systems, but will rely on wells, springs or streams. Shallow groundwater and surface water are particularly vulnerable to pollution, and with no treatment or disinfection being normally applied, there is considerable concern in practically every country over individual water supply systems.

Large numbers of people are involved. For example, 86% of the rural population of Romania is served by individual wells, springs or public fountains, and in Poland 60% of rural villages are served by individual wells. In Turkey, 4 million people have no access to a public water distribution system.

The microbiological quality of the water in individual systems is often poor. The provision of effective disinfection is not easy, however, because of both the costs and the shortage of skills required to operate it. There is also resistance to its introduction. For example, cartridge chlorination units, which are immersed in the well water, are available, yet people do not like having these devices in their wells, nor are they prepared to tolerate the taste of chlorine. They prefer to drink the untreated and possibly unwholesome water.

There are often difficulties in monitoring the quality of water in individual systems. Responsibility is entirely in the hands of the public health authorities but, because of the number and remoteness of these systems, monitoring is extremely infrequent.

Protecting wells against contamination can be difficult. In backward areas users may not be aware of its importance and, even when they are, they may not realize that some of their habits and practices are deleterious.

The regulation of individual wells is variable. In France, they are not regulated. In Spain, no quality standards are specified, except for places of public refreshment, but users must submit samples of water for analysis as proof of its safety. In some countries, such as Czechoslovakia and Romania, there are standards for the construction and protection of individual wells. In many countries, the public health authorities are empowered to forbid the use of wells whose water is considered unsafe to drink.

Among the frequent causes of contamination are unhygienic methods of drawing water from wells, particularly those involving ropes and buckets; the absence of adequate covers; the seepage of human and animal wastes into shallow groundwater; human, animal and avian intrusion into surface waters; and the injudicious disposal of domestic and other wastes.

Sources and their protection

Wells and boreholes are the predominant source of water in rural areas. In Portugal, 94% of sources are boreholes, in Hungary 75% and in Spain 60%. Surface waters are exploited to a large extent in some countries, notably melting glaciers and snow in Switzerland and the relatively pure mountain lakes and streams of Norway. In the United Kingdom, the sources of rural supply are split evenly among boreholes, springs and surface waters, with loch waters being particularly important in Scotland. In Romania, it is possible to exploit the River Danube only in the south of the country, because of the location of the river along the southern frontier. In Poland, surface waters may be used to serve groups of villages. The larger unit of supply makes operation of water treatment plants more feasible.

Because of the general difficulties with the provision and operation of adequate treatment plants, it is a common strategy to opt for sources of good quality that need only minimal treatment, if any, even though they may be distant and require considerable mains-laying.

There are legal provisions for the protection of sources of potable water in most countries. There is widespread concern, however, about the effects of agriculture, particularly from the increased use of pesticides and artificial fertilizers. Zones of protection and other measures have been adopted and can be effective against many types of pollution, but not against pollution resulting from accepted agricultural practices. Nitrogenous fertilizers are a major contributor to the nitrate concentrations that appear in both groundwater and surface waters. One country in central Europe reported that nitrate concentrations often exceed 40 mg/l in some areas and that the rate of increase is 1 mg/l per annum. Another country has tight controls on the use of fertilizers, but there is no knowing at present how useful such controls are in limiting nitrate seepage.

There is general recognition of the importance of making adequate arrangements for the disposal of sewage. The increase in water consumption arising from the provision of a new water supply can lead to new disposal problems and the possible contamination of the community's water source.

Treatment

In general, individual water supply systems are not treated, even though the quality of water is lower than that of community supplies. Cartride-type chlorination devices are available for the disinfection of wells, but it was reported that there can be considerable opposition to their use from consumers.

The treatment of community supplies depends very much on the type of source used. Norway makes considerable use of mountain lakes and streams; the water is pure and 80% of rural supplies need no treatment at all. In Switzerland, however, such waters are disinfected to ensure their safety. In Scotland, upland lochs and streams are a major source of rural supplies and a very small number of such supplies receive no treatment or disinfection. There are no medical problems with such supplies provided that the population served is long-established and static. It is recognized, nevertheless, that these supplies will have to be disinfected eventually.

Elsewhere, surface waters are treated, usually at least by sand filtration as well as disinfection. In Poland, surface waters are sometimes used to provide water for a group of communities and the increased scale of the operation makes feasible the use of slow sand filters in addition to disinfection with hypochlorite.

In most countries groundwater, whether shallow or deep, is the main source of rural community supplies. In Turkey, nearly all rural supplies are derived from boreholes and springs, and only 10% of sources are disinfected. The need for disinfection is avoided wherever possible at present by selecting only good quality sources. In Spain, almost all rural water supplies are disinfected. There was great pressure for this after the outbreak of cholera in 1976. Likewise, in Portugal, almost all rural supplies are disinfected and corrosive waters are also pH corrected, excessive iron concentrations are removed, and soft waters are hardened to counter cardiovascular disease. Poland and Hungary have major problems with iron and manganese. In Poland, sand filters are sometimes used to remove these substances but the preferred option is to relocate wells and boreholes or to abstract from a different level. Hungary has a special problem of methane in groundwater from the great Hungarian plain. This necessitates degasification and the plant used for the purpose incorporates an iron removal filter.

Methods of disinfection vary from country to country. Hungary makes considerable use of gas chlorination, and this is also used in the United Kingdom for boreholes, although not usually for spring and surface waters. Where disinfection is practised in Norway, one third is by ultraviolet irradiation. Elsewhere, hypochlorite is the most common technique, usually as a sodium hypochlorite solution. Gas chlorination is not well suited to remote sites where cylinders may have to be manhandled and where there may be problems of availability, safe storage and safe operation.

Mains electricity supplies are often unavailable at remote rural sources and this restricts the types of disinfection equipment that can be used to those that are less reliable. The unreliability of appropriate disinfection equipment is a common complaint.

In no country is it reported that the dose of disinfectant is related to chlorine demand. Where an electricity supply is available the disinfectant dose can be more readily related to flow, and such systems are common in Hungary, Norway and Portugal. If electricity is not available then flow-related dosing can be powered by gravity, but it is more likely that the disinfectant will be dosed at a constant rate.

It is normal for treatment and disinfection plants to be located near the source where it is often more difficult to install a mains electricity supply. If plants were located close to the nearest consumer, electricity could be provided more easily and a wider choice of equipment would be available. Chemical disinfection requires a finite contact time before becoming effective, however, and on balance it is considered preferable to locate the equipment near the source.

Responsibility for provision, operation and monitoring

There is a wide variation in the means of providing rural water supply systems. Construction may be the responsibility of local government, as in Norway, Portugal, Romania and Spain. In the USSR, local government collaborates with state and collective farms in constructing systems, and the farms bear the costs. In Czechoslovakia, France and Turkey, systems are provided by central government ministries. In Macedonia, state assistance is provided through the Republic Institute of Public Health, which then collaborates with the communities to be served in constructing the system. In Hungary, Poland, Switzerland and the United Kingdom, the water supply authorities are responsible for construction. In Scotland, the regional councils are the water supply authorities.

In all but a few countries, state subsidies are available. The extent of the subsidy varies from total, as in the case of Turkey, to shared costs, as in Poland where the owners of farms contribute on the basis of their income, not of the cost of the scheme. In France, finance is raised by the Ministry of Agriculture through a levy on horse-racing, as well as through a central funding organization.

The operation of rural public systems is largely in the hands of local government throughout the Region. The type of local government unit varies, from village councils in Turkey, through some larger district administrations, as in Portugal, to the regional councils in Scotland. There are exceptions. In both Czechoslovakia and France rural water supplies are central government functions, the responsibilities of the Ministry of Forests and Water Management and the Ministry of Agriculture, respectively. In Switzerland, water supplies are the responsibility of local water boards. In Poland and in England and Wales, there are regional water authorities that also have responsibility for wastewater disposal. The Polish regional authorities have a rural water service function only.

Surveillance — i.e. the assurance of water quality and often of sufficiency as well — is the ultimate responsibility of the public health authorities. This may be at the local level or it may be a function of ministries of health on a regional basis. In Switzerland, the water supply service carries out the monitoring itself on behalf of the health authorities. This is also the practice in the United Kingdom although the local authorities, as part of their environmental health and consumer protection functions, are responsible in law. In Spain, surveillance is carried out by provincial health authorities if district bodies are unable to do it. In Portugal, water quality is monitored by local health centres that are coordinated by the national Directorate-General of Health. In the USSR, the Ministry of

Health ensures that adequate facilities are available at the sanitary and epidemiological stations set up in rural areas, and these stations monitor rural water supplies.

As regards quality, no country applies different standards to rural communities and urban communities. Although it is recognized that water in rural supplies is, at present, often inferior in quality to that in urban supplies, this is always seen only as an interim fact and a matter for eventual rectification.

Each country has its own national standards, but in practice they are normally based on one of the WHO standards. The Commission of the European Communities has set its own standards for its Member States, and these will be applied from 1985 onwards. The USSR has specified limit concentrations on 804 chemical substances in surface waters, and on 28 chemical contaminants of soil.

Quality problems

The primary requirement of a water supply is that it should be sufficient and safe. Rural communities are usually provided with such a supply after urban needs have been met. The status of rural water supplies in any particular country usually reflects its state of development. The first consideration is the eradication of epidemic diseases, and wholesome water is an essential element. Thus, in Turkey, priority is given to those regions where the risk of epidemic disease is highest.

Problems of sufficiency are widespread throughout the European Region in rural areas in the summer months, but are particularly acute in the south. In southern Spain there is the additional problem of excessively saline groundwaters.

The provision of an adequate water supply, with the concomitant increase in consumption, can bring its own problems unless steps are taken at the same time to provide an adequate sewage disposal system. For example, only 20% of the rural population in Hungary and 35% in France are connected to a waterborne sewerage system at present. The lack of sewerage schemes is an inevitable threat to water supplies, particularly as regards microbiological quality.

Various other potential hazards have now been recognized. They are not necessarily confined to rural water supplies, but the difficulty in applying adequate treatment technology to them will add to the problem. In Norway and the United Kingdom, many upland sources are derived from peaty ground and are soft and acidic. This can make the water corrosive to distribution and plumbing systems and result in inadvisably high concentrations of metals, including lead, copper and zinc, in tap-water. Furthermore, the chlorination of water containing humic substances derived from peat may give rise to organochlorine compounds. In Czechoslovakia, limits are set on the concentration of humic substances.

The intensification of agriculture with the increased use of artificial fertilizers and pesticides is a growing problem for water supplies all over the Region. The injudicious use of pesticides can lead to the contamination of surface waters while the seepage of nitrogenous fertilizers can cause an increase in nitrate levels in both surface waters and groundwaters. Nitrate removal may be feasible from large-scale supplies, but it is not yet feasible for small rural supplies. There may be a limit to which existing contaminated sources can be abandoned in favour of perhaps more distant sources of better quality. Nitrate is universally recognized as contributing to methaemoglobinaemia in infants but it may also contribute to the formation of carcinogenic nitrosamines in the gut of adults.

Many countries in the European Region must now have greater recourse to surface waters for rural supplies. The problem of organic micropollutants then arises if the water is subject to effluent disposal upstream from an abstraction point. Again, the technology of removal is less likely to be available for rural supplies. If treatment is confined to disinfection by chlorination, the problem could be exacerbated by chlorination products.

Operation

Almost by definition, rural water sources and treatment plants are often located at remote sites. Surface water and spring sources, in particular, are frequently at some distance from the communities they serve. There are two principal options for the operation and maintenance of these supplies: operators attached to a particular supply, or mobile teams. There are disadvantages to each.

The operation and maintenance of a small rural supply is not likely to justify full-time attendance, and part-time staff will have to be recruited locally. There is then the problem that suitable staff are not always available. There is no general rule and the situation will vary from community to community. In the USSR, the state and collective farms can take the initiative and supply the necessary personnel. On any large farm anywhere, there will be people who have received technical training of some kind. In Romania, rural water treatment plants are at present installed largely to serve communities where small industrial enterprises, such as food processing, have been established. These enterprises are also able to provide suitable operating staff.

By contrast, where agriculture is based mainly on smallholdings in scattered communities, there are less likely to be technically trained people and there will be resistance to releasing people for work that may not be seen as of any direct benefit to the farm. There is often a lack of awareness of the benefits of a wholesome water supply. In less developed areas where the operation of rural water supplies is the responsibility of the villages they serve, there is often little interest in them and their operation is neglected. The policy may then be to avoid the need for treatment wherever possible by exploiting only good quality sources even over long distances. The problem is most acute where communities are scattered and where people, particularly older people, may have only limited education. There is then less chance of the health authorities being able to promote successfully the benefits of an adequate water supply than there is in a more cohesive community that may have its own long-established social institutions or where there is a central focus of employment.

Periodic attendance and maintenance by mobile teams have the merit that they are carried out by qualified staff, but the disadvantage of high cost. Teams are responsible for a number of sites and much of their time is spent travelling between them rather than attending to the plant itself. Much more staff is needed than is technically warranted by the volume of water involved. The cost of operation and maintenance often exceeds the income received from the consumers.

A vital aspect of the availability of skilled operators is the training facilities provided. These vary greatly from country to country. In the United Kingdom, for example, the training of water service personnel is well established at all levels. Operational training is coordinated nationally by the water suppliers themselves. National training programmes have, in recent years, been introduced in France, and coordination between the various bodies responsible has been improved. By contrast, no central training schemes have been established in Portugal to date. Municipalities and their rural equivalents are responsible, but are too small to be effective.

Charges to rural consumers

The charges levied in the European Region cover the entire range from no direct charge to the full recovery of costs. It is exceptional for no direct charge to be made. Only in Turkey are the capital costs of rural supplies met from central government funds, and the supplies are then in the hands of village councils. In the USSR and Macedonia, no charge is made for distribution as such, but payment is made for treatment when it is done in the former, and for energy when it is required in the latter.

In France, Norway, Portugal, Switzerland and the United Kingdom, charges must cover production costs and, in the last three countries, capital costs as well. In France, the capital costs of rural supplies are met partly by a levy on horse-racing and partly by central funds.

The method of charging varies from country to country. For example, in Spain and Portugal water supplies to households are metered and charges are based on the volume supplied. On the other hand, in Norway a local tax is levied to pay for water supply, and in the United Kingdom the vast majority of domestic consumers are charged a water rate, which is effectively a tax based on the annual rentable value of the dwelling; this is paid to the water supplier, whether a statutory water company, the regional water authority or, in Scotland, the regional council.

THE TECHNOLOGY OF WATER TREATMENT AND DISINFECTION

The primary purpose of water treatment is to render the water fit to drink. This requires the improvement of microbiological quality and the control of dangerous chemical substances and of metals. Secondary purposes include the protection of distribution and plumbing systems (e.g. the control of corrosiveness) and the maintenance of the aesthetic quality (e.g. taste, odour, colour and hardness).

The first subgroup considered all the technologies used for water treatment and assessed their applicability to rural water supplies. The bulk of this section of the report is a process-by-process technical examination and, while local factors are clearly of paramount importance, suitable approaches are recommended wherever possible.

Classification of sources

The treatment requirements of water for potable supply in rural areas depends on the quality of water required and the quality, and variation in quality, of the source. Table 2 shows the range of sources, together with the contaminants that may be present in each. There are differences in nomenclature in the various countries of the European Region and there are differences in detail in the methods of abstraction. Nevertheless, it is believed that most situations are covered by Table 2. Inclusion of a contaminant in the table does not necessarily mean that its concentration must be reduced in all cases. The need for contaminant reduction will depend on the initial concentration and the target quality.

Treatment processes

The processes available for the treatment of potable water, applicable to rural areas, are grouped together according to function, and assessments are made of the suitability of each for particular circumstances. It must be recognized, however, that a treatment process that may be appropriate for use under certain conditions may not necessarily be appropriate for use elsewhere. It will depend on the quality and availability of operator skills

Table 2. Water sources and potential contaminants

Source	Contaminant
Deep groundwater (boreholes)	*Fe, Mn* Colour, H_2S, NO_3, NH_3, CO_2 (pH)
Shallow groundwater	*Fe, microorganisms* NO_3, NH_3
Infiltration water	*Fe, colour, organic matter, taste*
Spring waters	*Fe,* CO_2 *(pH)*
Rainwater (cisterns)	*Microorganisms, constituents of atmospheric pollution, pH*
Surface waters (streams, rivers, lakes and reservoirs)	*Suspended solids, microorganisms, colour, algae, taste, odours, organic matter* NO_3, NH_3

Note: The most important contaminants relevant to each source type are italicized. They are considered important when they are directly associated with, hinder, or are caused by, the control of microbiological quality.

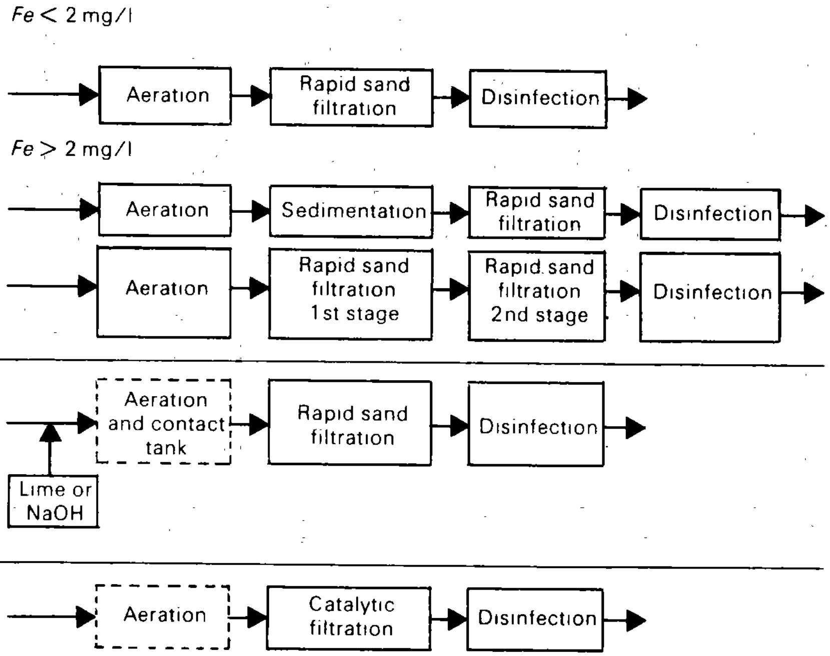
and on the availability of other resources such as materials and electricity. In some circumstances it may be advisable to concentrate on capital expenditure, for example to maximize reliability and to minimize manpower requirements. Table 3 gives examples of the selection of treatment processes to deal with certain typical situations.

Several processes were not included in the detailed discussion because the subgroup did not consider them appropriate for rural situations. A brief mention of them, with the reasons why they are not recommended for use with rural water supplies, will be found on p. 21. The exclusion of a process should not be taken as necessarily implying that the purpose for which it is used at larger water treatment works is not important for rural supplies. In many cases the recommendation is that more effort should go into the development of techniques that will be appropriate for rural conditions.

Disinfection

Continuous, reliable disinfection is essential in many circumstances, and even where not essential it is a prudent measure. Even though a source may

Table 3. The selection of a treatment process in some typical situations



Source of water	Main contaminants	Treatment process
Deep boreholes	Fe (carbonate form) (+ Mn)	*Fe* < 2 mg/l → Aeration → Rapid sand filtration → Disinfection →
		Fe > 2 mg/l → Aeration → Sedimentation → Rapid sand filtration → Disinfection →
		→ Aeration → Rapid sand filtration 1st stage → Rapid sand filtration 2nd stage → Disinfection →
	Fe (sulfate form)	Lime or NaOH ↑ → Aeration and contact tank → Rapid sand filtration → Disinfection →
	Mn + Fe	→ Aeration → Catalytic filtration → Disinfection →

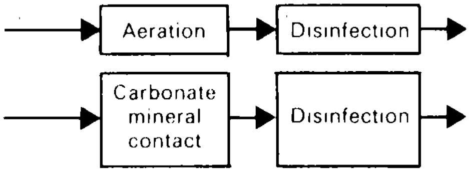
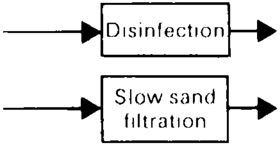
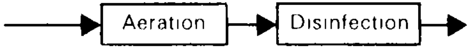
	Fe in humic acid compounds	Because of the need for coagulation another source of water should be considered
	CO_2 pH < 7	
Shallow boreholes and surface collectors	Bacteria	
	Fe	As for deep boreholes
Springs	CO_2 pH < 7	
	Fe (carbonate form)	As for deep boreholes

Table 3 (contd)

Rainwater (cisterns)	Bacteria	→ Disinfection →
Surface water (streams, rivers, lakes and reservoirs)	SS, bacteria	→ Screening → Slow up-flow sand filtration → Disinfection →
	SS, COD (organic substances), bacteria	→ Screening → Sedimentation → Slow sand filtration → Disinfection → → Infiltration → Disinfection →
	SS, COD, bacteria, algae, taste and odour	→ Screening → Sedimentation → Slow sand filtration → Disinfection → Chlorine (pre-chlorination) Potassium permanganate (after chlorine)

Note: The boxes drawn with broken lines indicate that the process is applicable under some circumstances but may be omitted under others.

be very good microbiologically, it can still become contaminated through natural disturbances and forestry and agricultural operations. Similarly, although the distribution system may be a sound one, maintenance or repair work on it and unauthorized interference with service reservoirs can result in contamination of the supply, and a disinfectant residual is therefore desirable as an assurance of microbiological quality.

There are several disinfection methods that can be used and, while each may have its own particular attraction, none is entirely devoid of problems or side-effects. Systems using hypochlorite are considered to be the most appropriate for rural water supplies. The on-site production of hypochlorite by the electrolysis of brine can have its advantages. Gaseous chlorine may also be used but there are difficulties in controlling the dose at very low flow rates. Proper safety precautions are essential for chlorine gas, and because of the danger its use is restricted in some countries. Ozone, chlorine dioxide and chloramine have also been considered but are thought to be inappropriate for use under rural conditions. Ultraviolet irradiation can be appropriate, however, when water quality is already good.

There are three degrees of effectiveness and complexity in methods of disinfection:

- dosage at a set rate: this is the simplest method but requires manual adjustment to respond to changes in water quality or rate of flow;
- dosage proportional to flow: the equipment required is more complex but the concentration of disinfectant applied will be constant;
- residual control: the equipment required is the most complex and relates the dose applied to the disinfectant demand of the water. It is thus the most effective in terms of disinfection. This approach, however, has not yet been developed satisfactorily for small rural supplies.

Annex 1 describes the six main disinfection systems. Further development of equipment for all methods of disinfection appropriate to rural water supplies is recommended.

Removal of suspended solids

The improvement of microbiological quality requires the removal of suspended solids. Solids may themselves be microbial, or they may be carriers of microorganisms. The removal of both large- and small-sized particulate matter is more likely to be needed with surface-derived waters than with groundwaters. There is a range of screening, settling and in-depth filtration processes. In some circumstances a single screen or filter may be adequate. In others a combination of processes may be necessary.

Water taken directly from a stream or river may first be passed through coarse or bar screens and then through strainers with a smaller aperture, or in extreme cases microstrainers. Some settlement of very large or dense solids will occur in the intake channels housing the screens. Channels or tanks can be provided specifically to permit sedimentation.

An alternative intake arrangement is infiltration through the bed or a bank of the stream into wells or tunnels. Infiltration can be enhanced by replacing the original bed or bank material with a more porous material. This engineering approach can be taken a stage further by constructing horizontal-flow gravel-bed prefilters. These are used in the Federal Republic of Germany and in Switzerland. Their application to rural water treatment is being developed in Botswana and Thailand.

The term filtration usually implies in-depth filtration through sand or other granular media. There are a number of variants, including rapid gravity and pressure downflow and upflow sand filtration. In Scotland, slow upflow filtration, without any biological activity and used in one- or two-stage modes, is common but needs further investigation. Filter construction normally provides for the frequent backwashing of the medium.

Slow sand filtration was probably the first method used for the purification of water for public supply. In general it produces water of good microbiological quality. A slow sand filter can be constructed on any scale and can be operated and maintained with few problems. In Yugoslavia, two-stage slow sand filtration is being developed with a coarse sand in the first stage and fine sand in the second.

The value of a slow sand filter can lie not only with the efficiency of a low filtration rate through a bed of relatively fine sand, but also with the action of the biologically active film of algae and other microorganisms that develop on the surface of the sand bed. Slow sand filters may be covered but are more usually open to sunlight to enhance the activity of the biological film.

Slow sand filters are not effective in removing natural colour but will remove turbidity. Both the film and the sand bed can be blinded, however, by high concentrations of suspended mineral particles or diatoms, or when the water quality causes fast algal growth. Some method for the preliminary removal of solids may therefore be necessary. The principles of design and operation are well presented by Huisman & Wood[a] but the process needs to be better understood and developed for use with rural water supplies.

In terms of simplicity of operation, a treatment sequence of screening, sedimentation and slow sand filtration has advantages over rapid filtration, although in some circumstances the latter may be necessary. There

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[a] **Huisman, L. & Wood, W.E.** *Slow sand filtration.* Geneva, World Health Organization, 1974.

appears to be a general lack of knowledge about the principles of operation of filtration processes and their variants, and further work on this is recommended.

The advantages and disadvantages of nine methods for removing suspended solids are described in Annex 2.

Corrosion control

The pH of acid waters, such as those from peaty areas, needs to be adjusted to reduce corrosion of distribution and plumbing systems. Raising pH will not only prolong the life of pipes and fittings but also reduce discoloration by the products of oxidation, and the dissolution of lead (and hence reduce the threat to health) and copper. On the other hand, an increase in pH intensifies the colour of humic substances that may be the source of the acidity in the first place. In addition, if pH is increased too much, the rate of dissolution of zinc may be increased and the effectiveness of disinfection, particularly by chlorine, will also be reduced.

In some cases a low pH is due to high concentrations of carbon dioxide. A satisfactory increase in pH may then be achieved by removing the excess carbon dioxide by air stripping. This technique is especially appropriate where carbon dioxide concentrations exceed 20 mg/l.

Where acidity is due to humic substances, an increase in pH can be achieved simply by treatment with alkali, either as a solution or, where suitable material is available, sparingly as soluble solids. These can include crushed chalk, limestone, semi-calcined dolomite, pelleted magnesium oxide, or even calcined mollusc shells.

Acid addition to correct very high pH values is not recommended for rural water supplies because of the problem of handling acids.

The advantages and disadvantages of three appropriate methods of corrosion control are set out in Annex 3.

Removal of iron

Iron in large concentrations will cause problems in distribution and will be noticed by consumers. If iron precipitates settle in the mains, they may appear at sudden high concentrations in consumers' taps with any subsequent surge. Similar effects occur when the corrosion of iron pipes leads to elevated iron concentrations. The settlement in mains can also lead to a loss of carrying capacity, and aggravate corrosion, microbiological activity and so forth. Particulate iron should not be allowed to become too high in tapwater, not only for aesthetic and operational reasons, but also for health reasons because it can be a carrier of microorganisms.

Poorly oxygenated groundwater with dissolved iron in a ferrous state can be troublesome, and it is necessary to oxidize the iron and remove the hydroxide precipitate which is formed. If precipitated iron concentrations are higher than about 2 mg of iron per litre, sedimentation or prefiltration may be needed before rapid sand filtration.

Iron can be readily oxidized by means of an efficient aeration system, provided that the pH is high enough. If manganese is also present at an undesirable concentration, then oxidation and removal is more complex and can require catalytic filtration. Where iron or manganese are chemically mixed with natural materials, coagulation followed by filtration is required and it is advisable to attempt to locate an alternative source of water. Two methods of removing iron are shown in Annex 4.

Control of taste and odour

Tastes and odours can arise from naturally occurring organic substances, pollution, algal growths and certain other microorganisms. Generally these tastes and odours are exacerbated by chlorination. Hydrogen sulfide, when that is the cause, can be removed by aeration.

The provision of a supply that is free from unpleasant tastes and odours is important if the consumer is not to resort to an alternative, possibly less safe, supply. Nevertheless, the removal or control of tastes and odours is not an easy task in rural situations and every effort should be made to use a source that is free from this risk.

If no such source is available, then slow sand filtration (after pretreatment with potassium permanganate) or granular activated carbon filtration can be used. These two methods are described in Annex 5.

Removal of natural colour

Natural colour in water sources suitable for drinking is mostly due to humic substances derived from peat. The acidic, low alkalinity surface waters from peaty catchments therefore tend to be the most highly coloured. The colour is considered undesirable by some consumers.

While the substances giving rise to the colour are probably not harmful in themselves, it is considered that high concentrations of the products of reaction between them and disinfectants may become a long-term hazard to health. It is therefore desirable to remove colour, both for aesthetic reasons and to minimize the formation of disinfection by-products. The highest priority, however, must remain disinfection to improve and maintain microbiological quality.

The most common technique used for colour removal is chemical coagulation followed by filtration with or without sedimentation. While this technology is well proven and widely practised on larger water supplies, the approach is rather complex for small rural supplies. It may be preferable therefore to find an alternative source. Disinfection can bring about a slight reduction in colour. Further research is required to develop simple techniques of colour removal, suitable for rural situations.

Additional processes

In addition to the processes examined in detail and discussed above, water softening and sludge disposal were considered briefly. It was concluded, however, that neither is necessary in rural situations.

The problem of nitrates in both groundwaters and surface waters, arising from the increased use of nitrogenous fertilizers, is gaining significance across the European Region and is relevant to small rural supplies. A great deal of research has been carried out in recent years into methods of nitrate removal, and both biological denitrification and ion exchange are now being practised successfully. As used, however, they are not particularly appropriate to rural supplies and further work is required. Similarly, different methods of ammonia removal are used at large water treatment works to avoid problems with chlorination, but these are not suitable for rural water works.

The present methods available for taste and odour control are considered to be more complex than is desirable and work should be carried out to develop simpler methods.

Water can become discoloured while in distribution systems because of the precipitation of iron from water that was not aerated beforehand, or because of the corrosion of iron water-mains. In addition to the methods already described, it is possible to prevent these problems by the addition of sequestering agents to prevent precipitation or of corrosion inhibitors. The use of chemicals for these purposes, such as polyphosphates and silicates, is restricted in some countries so that these methods do not have universal application. More information is needed on the effects of these chemicals to ensure that they are not misused.

SUPPLYING WATER TO RURAL HOUSEHOLDS

The second subgroup made recommendations about techniques for supplying water to rural communities and individual dwellings, taking account of social, technical, cultural, topographical and climatic conditions. The discussion addressed three main points: source selection, source protection, and distribution. More detailed information than that summarized below may be found on all these subjects in the bibliography (Annex 6).

General considerations

The provision of water supplies to small communities must be considered within the context of regional plans and take account of cost, geography, technical expertise and, where appropriate, cultural preferences. Water quality is nevertheless the major consideration in designing a system and preference ought to be given to using the best quality water available. Often this will be groundwater.

Allowance must be made not only for present and future domestic requirements, but also for future agricultural and industrial development. Several alternative schemes should be studied and plans must take account of existing water supplies. Advantage should be taken of existing managerial and administrative structures and the availability of technical expertise.

Plans for new or improved rural water supply systems must always be made in conjunction with plans for adequate sewage disposal systems. This is essential to avoid, or at least minimize, the danger of contamination of water sources or resources with sewage.

With new schemes the possibility should always be considered of connection into existing supplies, following their expansion, provided the quality, quantity and reliability of these existing supplies has been proven. A second possibility that should be considered is grouping a number of villages into one system supplied from a common source. Both these approaches have the advantage of supplying water from a single large source that can be more effectively controlled and more regularly monitored. In general, the proliferation of a series of small sources must be discouraged since this will fragment monitoring and supervision.

All schemes should be planned on a regional basis. Several alternative solutions should be studied and decisions made on the basis of water quality and quantity, topography, cost and the technical expertise available. Planning on a regional basis will provide the advantage of uniform design and supervision. As part of regional planning, an inventory of sources should be drawn up for future use. Information should be gathered on their quality, quantity, rate of production, and depth. The protection of these sources must be undertaken on a long-term basis. The best quality water must always be reserved for potable supplies.

The following plan of action is suggested for improving water supply systems.

- Fully assess an existing system before expanding it to meet new needs.
- Take advantage of collective planning on a regional basis to ensure a uniform approach in design and to prevent an unnecessary proliferation of sources and a fragmentation of effort.

- Draw up an inventory of sources, reserving the best quality sources for drinking-water supplies. Establish a system for the long-term protection of these sources.
- Proceed with the exploitation of these sources alone to meet current needs.

Although no mention was made in the general discussions of self-help schemes, they are often essential in developing countries and it might be appropriate for them to be considered in some European situations as well.

Source selection

The best quality source of water available should always be reserved for potable supplies, to avoid or to minimize the need for treatment. The prime objective must be to provide safe drinking-water, but if other needs can be met by the same source, then provision to do so may be made. Possible sources of drinking-water are listed in Table 4 with an indication of their

Table 4. Applicability of sources to rural or dispersed communities

Type of source	Applicable to isolated houses or farms and small communities (yield < 2 l/s)	Applicable to larger communities (yield > 2 l/s)
Groundwater		
Spring water	yes	yes
Galleries	no	yes
Deep groundwater (boreholes)	yes	yes
Shallow groundwater (wells)	yes	yes
Infiltration galleries	no	yes
Surface water		
Streams and rivers	yes[a]	yes
Lakes	yes[a]	yes
Reservoirs	yes[a]	yes
Direct catchment		
Rainwater (cisterns)	yes[b]	no

[a] It is necessary to take into account that these types of source need the kind of treatment that may not be easily available for the smallest supplies.

[b] Due to the limitations set by seasonal variation in quantity and quality, and by the storage required, the use of rainwater is not advised unless no other source is practicable.

suitability for supplying communities of various sizes. The sources are listed in order of probable purity, the sources of better quality water appearing first.

Groundwaters. These are the preferred source of water, provided the topography is suitable. Protection of the aquifer from pollution is necessary. Groundwaters come from springs, wells or boreholes, and infiltration galleries. Springs avoid the need for pumping; the year-round adequacy of their flow must be ensured; they are vulnerable to pollution so they require protection; their quality depends on the geology of the area and the time of year, so expert advice must be sought; and galleries may improve the protection of the source, the yield and the reliability. Wells and boreholes require pumping but the provision of power for pumping will ease the problems of treatment, especially disinfection; they tend to be less vulnerable to pollution since they are more protected, but expert advice should be sought; and their quality will depend on the geology, so treatment may be necessary to remove iron, manganese, sulfur, methane and ammonia, as salinity and high amounts of dissolved solids may impair the quality. Infiltration galleries are primarily a treatment process that can be used, depending on the water quality, as the main treatment step; they are subject to clogging and vulnerable to pollution; and the quality of water is related to the quality of the adjoining river.

Surface waters. These include streams, rivers and lakes. They are more vulnerable to pollution than groundwaters; intakes should be sited upstream of known sources of pollution; the water quality can be very variable depending on seasonal factors and man's activities in the catchment serving the source; the storage of surface water will diminish the effects of pollution, even out seasonal differences and help maintain supplies in times of drought, but may be subject to eutrophication; and treatment, especially disinfection, is considered essential to ensure quality at all times.

Rainwater. Its use is advised only where no better source is available; it may be vulnerable to the effects of air pollution; storage facilities must be provided; catchments and storage tanks must be protected from pollution; and it may require mineralization.

Coordination of policy is necessary between those responsible for drinking-water supply and those responsible for water resource management, so that other uses do not interfere with exploitation for potable supply. This is particularly so with regard to the use of groundwaters and the effects of pollution in general.

The final selection of the source is made on the basis of an evaluation of the local situation, taking into account such factors as hydrological conditions, the quantity of water available, human activities and the implications of long-term planning. Fig. 1 is a flow chart of source selection.

Source protection

It is essential that once a source of good quality water has been identified and exploited, its quality is protected from pollution. Sources that might be used in the future must also be protected.

Before exploiting a source a sanitary survey must be made. This surveillance should be maintained while the source is being used. Where resources for sanitary surveys are limited, priority must be given to surveillance related to source selection. Sanitary surveillance should be undertaken by a specialist agency.

It is better to protect a source, particularly a groundwater source, than to treat the water once it has become polluted. For some pollutants, protection is the only technology available. In addition, the provision of special treatment facilities in the event of pollution may be impracticable at small sources. Finally, sampling relates only to the quality of the water at the time of sampling — it may not detect intermittent pollution.

Agriculture is a major source of pollution, reflecting the industrialized, intensive nature of modern agriculture with its dependence on heavy usage of fertilizers and pesticides. The nature of the problem will vary from area to area and in some areas air pollution, by acidifying soil, may aggravate the problem of pollution by nitrogenous fertilizers. In addition, the use of surface active agents in pesticides may modify the rate at which pollutants percolate through the soil.

It will not always be possible to prevent the pollution of rural sources, because they lack treatment facilities, and this makes them especially vulnerable.

When monitoring the quality of sources, preference should be given to: parameters of primary health significance such as microbiological quality; the regular monitoring of nitrate levels in those aquifers at risk; and operational monitoring and control. Two kinds of source protection should be considered: legislation, control and planning to limit long-term degradation in quality on a regional basis; and the local, immediate, physical protection of individual systems.

In developing appropriate national and regional safety standards, the recommendations given in the WHO *Guidelines for drinking-water quality*[a] should be taken into account as well as other existing national and international standards.

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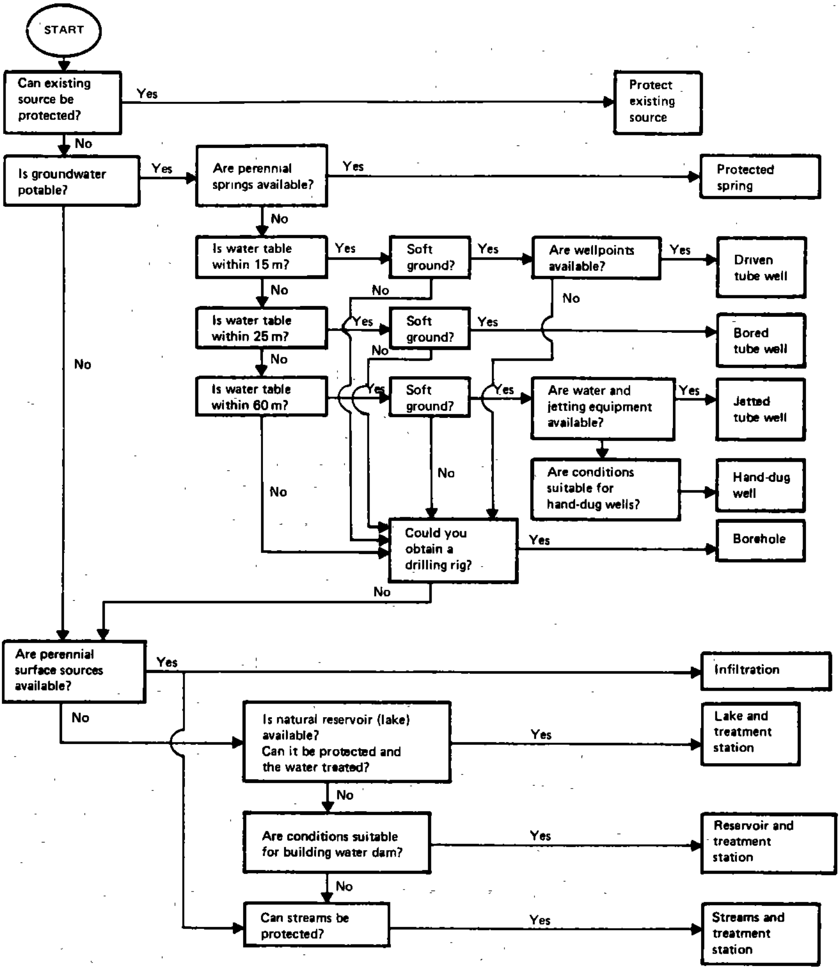
[a] *Guidelines for drinking-water quality.* Geneva, World Health Organization (in press).

Fig. 1. Source selection



In general, the design and siting of each scheme must be approved and meet the requirements set out in various WHO publications (see Bibliography, Annex 6). Specifically, the direct entry of pollutants must be prevented; equipment must be protected from mechanical damage and be of a robust design; appropriate site drainage must be provided; facilities must be sited away from obvious sources of pollution; and activities in the immediate area and access by people and animals must be controlled.

Surface sources are more vulnerable to pollution than groundwater sources, and intakes should be sited upstream of known sources of pollution. The intake itself must be protected from damage and pollution.

Zones of protection are needed for groundwater sources but there may be problems in establishing and monitoring them in rural areas. Expert advice must always be sought when establishing these zones since much depends on the topography and geology of the area.

To ensure continued source protection and to minimize the risks of pollution, the education of consumers is very important. In addition, the education of farmers about the effects of agricultural practices on the present and future quality of water supplies is desirable. Attention should be paid to modifying agricultural practices to reduce the release of nitrate and other chemicals into aquifers and into surface waters, and more research is necessary.

Distribution

Having ensured a safe source of water, attention must be paid to ensuring that the distribution system is effective and safe.

Pumping

Whenever possible, gravity should be used so that pumping problems — breakdowns, lack of spare parts, maintenance — are avoided. Where pumps must be used, especially where electricity is available, then treatment, particularly disinfection, becomes easier to apply and control. In general, to minimize the risks of pollution, wells should be capped and buckets and ropes must not be used. When operating a gravity system, care must be taken in the siting of treatment plants so that sufficient head is provided to power the process.

Appropriate design

The design and construction of the distribution system must be in line with published guidelines, and must have the approval of the competent water and health authorities. The yield of the source and the design of the system should be such as to meet all planned demands for drinking-water. Continuous supplies are always preferable because they reduce the risk of infiltration and back-siphonage. When intermittent supplies are unavoidable, consideration should be given to the provision of a safe system of domestic storage. When consumers are responsible for installing storage tanks for themselves they tend to over-store and then to discard the excess once the supply has resumed. This practice leads to a considerable waste of water.

Distribution reservoirs

Distribution reservoirs are generally desirable; the need for them and their use are discussed by Wagner & Lanoix.[a] The design, siting and construction should be in line with published recommendations such as those given by Wagner & Lanoix, and special consideration should be given to the prevention of pollution. Construction materials should not lead to a deterioration in water quality. When designing reservoirs the needs of water usage other than drinking-water, fire-fighting for instance, should be considered if the provision of these facilities does not conflict with the primary purpose of supplying drinking-water.

When designing reservoirs, consideration should be given to providing sampling taps and facilities for draining and disinfecting the water; and preventing deterioration in quality during storage, short-circuiting, and static areas.

Outlets

Connections to individual houses are preferable. Where community size, distance between dwellings, topography and cost make this impracticable, however, then public stand-pipes will be required. Such public outlets must be under the control of the competent authority and designed and sited so as to prevent pollution and wastage. The site should be well drained and preferably paved. Taps should be of a durable construction to minimize vandalism.

If efficient usage needs to be checked then meters should be installed. It is impracticable to use such meters as the basis of a charge system but they should be used to provide information to improve the management of such schemes.

To discourage the practice of drinking water directly from the standpipe, separate public drinking-water fountains should be provided of a design that prevents contamination of the outlet.

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[a] **Wagner, E.G. & Lanoix, J.N.** *Water supply for rural areas and small communities.* Geneva, World Health Organization, 1959 (Monograph Series, No. 42).

Leakage and wastage control

Leakage and wastage should be restricted with a good system design using durable materials and by efficient operation and maintenance. Plumbing systems must be designed to protect health and prevent contamination and wastage.[a] Where water and soil conditions are aggressive, materials must be resistant to corrosion.

Taps that turn off automatically should be used for public stand-pipes and fountains. Instructions should be given to consumers on the need to avoid waste and how to go about it. Inspection for leaks and wastage is important, and can be done in conjunction with sanitary surveys.

Cleaning and maintenance

Before introducing water into a distribution system for the first time, the system should be cleaned and disinfected. Repairs should be conducted in a hygienic manner and, where possible, the system disinfected before return to service. The system should be cleaned periodicially to prevent the accumulation of debris and corrosive products.

Emergency supplies

The transport of potable water in tankers is not an appropriate practice for Europe, except during emergencies. When planning supplies to rural communities, the provision of emergency water services should also be considered.[b]

Domestic wastewater disposal

The planning of water supply and wastewater disposal systems must be coordinated. In particular, the wastewater disposal system should be such that the pollution of existing and potential sources of drinking-water is avoided and contamination of the distribution system prevented.

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[a] *Guidelines on health effects of plumbing.* The Hague, The International Reference Centre for Community Water Supply and Sanitation, 1982 (IRC Technical Paper Series, No. 19).

[b] **Assar, M.** *Guide to sanitation in natural disasters.* Geneva, World Health Organization, 1971.

ORGANIZATIONAL STRUCTURE

Each member of this subgroup outlined the existing organizational structure in his country and presented its merits and deficiencies in relation to the provision of rural supplies.

The prime purpose of providing a safe water supply is to safeguard health but at an early stage in the discussions it became very apparent that the aims of different countries in Europe varied widely, from the simple need to provide a water supply at all, to the desire in more developed areas to meet the current high standards for water quality. This made it difficult to arrive at an agreed definition of the type of supply that ought to be the subject of discussion.

It was generally accepted, however, that rural supplies might be considered as those that serve small communities (say less than 2000 persons) and that present special problems such as:

- remoteness
- lack of suitable manpower
- high installation and operating costs per head of population
- difficulty in providing equipment, spares, maintenance, etc.

Under such circumstances it is advisable that ultimate responsibility for water quality surveillance should lie with an independent public health authority, while responsibility for the supply should lie with the local community. At this level there will be greater motivation and interest in providing a supply or improving an existing one and in operating the system to the highest possible standard. On the other hand, however capable they may be, local operators still need technical support from a higher level. The regional authority should be actively involved in rural supplies, in setting design, maintenance and operational guidelines, and in providing logistical support for any problems that cannot be dealt with locally.

Surveillance

Surveillance should cover water quality, and engineering and operational aspects, and ensure that these conform with the established guidelines. For water quality surveillance, two levels are suggested because of the special problems, such as lack of local expertise, presented by many of these supplies.

Local surveillance should be based on useful parameters that can be determined easily and interpreted by local personnel on a daily basis, such as residual disinfectant and turbidity.

Regional surveillance should use parameters that require more extensive laboratory facilities and that should be determined on a less frequent basis by the regional health authority.

The need for additional surveillance can be minimized by the careful study and selection of the source at the planning stage and by safeguarding the catchment by regular inspection and adoption of suitable protection measures. Surveillance of the engineering and operational aspects should be performed by the regional authority and include plant maintenance, catchment protection and leakage control.

Operation, maintenance and training

Regular maintenance and correct operation are very important and there are two viable options, the choice depending on local circumstances:

- mobile work teams, provided by the regional authority, operating from a central base and attending to several supplies;
- employment of a local person on either a full-time or a part-time basis to carry out simple maintenance with support from the regional authority when necessary.

It is important that local personnel should be provided with basic guidelines and appropriate training. Motivation will be increased by explaining the importance of the task and by ensuring that the employee has a full understanding of his job. A formal system of recording daily routine measurements, action and incidents should be implemented.

The training of personnel involved in operation and maintenance should be at a level appropriate to their tasks and should include technical, safety and health instruction. A formal training system does not exist in all European countries. At the very least, a set of operating and maintenance guidelines for various types of supply ought to be developed.

Documentation of supplies

Well documented records of supplies are an advantage as it is only by analysing these records that problem areas can be identified and quantified. Present exercises of assessing the problem of rural supplies based on data obtained from a questionnaire can give only a limited overview.

Although the task would be a large one, an updated and as complete as possible survey of the problematic supplies in Europe should be undertaken. An appropriate way would be for countries to publish statistics in a common form. Guidelines could be provided for the format of presentation to facilitate comparison among countries.

Finance

There are different charging policies throughout Europe, varying from total recovery of costs to only a nominal contribution by the community. The community ought to bear at least part of the cost of providing the supply. This has two advantages: it gives a feeling of possession and responsibility for the system; and metered supplies provide a useful tool for controlling usage when conservation measures have to be adopted.

Private supplies to communities are uncommon in Europe and therefore individual systems only were discussed. Individual systems should be monitored by the appropriate health authority and information and technical and logistical assistance should be provided when improvements are needed.

As far as the implications of individual supplies in terms of social cost are concerned, it may be that the cost of providing assistance to improve supplies will be compensated by reductions in other costs such as medical care.

Public education

Public awareness and knowledge of the importance and characteristics of water supplies could be achieved by environmental education including such aspects as:

— the hygienic implications of a good water supply

— the need to conserve water

— the protection of catchment areas

— a practical knowledge of water supply systems.

CONCLUSIONS

1. All countries of the European Region are faced to a greater or lesser degree with the problem of providing water to rural areas.

2. All countries recognize the importance of safe and adequate water supplies to all sections of the population as one of the key elements in primary health care.

3. The provision of a safe and adequate water supply to the as yet unsatisfactorily served rural population is one of the main tasks of the

European Region if the goals of the International Drinking Water Supply and Sanitation Decade (IDWSSD) are to be attained. As such, this is one of the Region's top priorities.

4. It was not felt necessary to define too strictly a rural community, as conditions vary widely throughout the European Region economically, culturally and socially. A categorization on the basis of population size alone would be arbitrary and misleading, but this is a question that will have to be resolved if an exercise in information collection, monitoring and intercountry comparison is contemplated.

5. Two basic problems were identified: the first-time provision of water and the upgrading of existing rural systems to comply with modern standards of sufficiency and quality. The first problem arises in less developed areas while the second is the concern of more developed areas where public aspirations have risen.

6. Rural supplies present problems of remoteness and scale that may make it impracticable simply to scale down systems used for larger supplies: for instance, difficult access to works, lack of electricity supplies, infrequent operational visits, and remoteness from specialist technical and quality control attention.

7. The choice of system and equipment depends not only on the technical problems but also on the availability of adequately trained operators and reliable supplies of any necessary chemicals. In many cases these non-technical factors may be of overriding importance.

8. Methods of financing the construction of new systems were reported to vary widely. Various degrees of financial, technical and organizational support are given by central and regional governments.

9. Because of difficulties in operating treatment and disinfection facilities and in assuring the continuity of their operation, source protection and the prevention of contamination, particularly bacteriological contamination, is of high priority.

10. The first priority in water treatment is reliable disinfection. Although there are many disinfection systems available, there is no one method that is best in all situations. There is a need to develop equipment that is simpler and more reliable in operation, and at the same time to apply controls in operation to match the raw water quality.

11. In all countries of the European Region the health authorities have responsibility for monitoring the hygienic quality of water supplies. This

safeguard to health must be supported by sampling and testing at the operational level.

12. The provision of an effective quality surveillance service presents many practical problems. The cost is high because of the distances involved in sample collection, and thus sampling is done only infrequently and is often inadequate. The range of analysis is also limited by cost and is largely confined to microbiological testing only, with chemical testing being very infrequent.

13. There is growing concern with the general increase in the concentration of nitrates in rural water sources. In the past the concern has been principally with methaemoglobinaemia (blue-baby syndrome), but there is now additional concern about the connection between nitrate consumption and the formation of carcinogenic nitrosamines in the gut. The nitrate problem arises in part from the indiscriminate or excessive use of nitrogenous fertilizers; methods of optimizing the application of these materials in agriculture, and reducing the seepage of nitrate into groundwater and surface water, would be advantageous.

14. Responsibility for operation and hygiene varies considerably and the system adopted must be compatible with the sociopolitical conditions, cultural environment and level of development. Under all conditions, however, the community plays an important role and the degree of its involvement and commitment is a key factor in assuring a satisfactory service.

15. When small communities have responsibility for operation, experience has shown that technical back-up support from a district authority in the case of breakdown is important.

16. One of the major problems, particularly in less developed areas, is the lack of suitable operating staff. Training schemes for staff are not well developed and there may be poor coordination between the local body responsible for water provision and the national or regional authorities who can provide training facilities.

17. In certain areas there appears to be a lack of appreciation of the benefits of a wholesome water supply, which can make it difficult to recruit local operational personnel. Consumers are often suspicious of the chemicals and in-well devices used for disinfection, preferring untreated yet less wholesome well-water.

18. There is a wide variety of methods for charging the consumer. These range from systems where the service is free (particularly in countries with

relatively poor rural populations where water is seen as a social service and an element of health strategy) to systems where the consumer is required to pay the full costs.

19. There are several specific problems related to rural water supplies within relatively limited geographical areas: iron, arsenic, heavy metals and methane in raw water. These problems require special technical solutions which, to be fully effective, must take due account of the limitations on technology that rural supplies set.

RECOMMENDATIONS AT THE NATIONAL LEVEL

1. Responsibility for the operation of a water supply should rest with the community being served.

2. Direct participation by the community in planning and construction should be encouraged. This normally fosters community spirit and helps to promote continuing successful operation.

3. Public awareness of the benefits of a safe water supply and of the risks associated with a polluted supply is an essential element in avoiding pollution arising from indiscriminate human activities, and public education programmes should be undertaken in schools and elsewhere.

4. Consumers should bear at least part of the cost of operating their water supply.

5. Assistance from a higher level organization (preferably regional) should be available for the technical and logistical aspects of water supplies.

6. Simple quality surveillance is an essential part of plant operation but should be supplemented by personnel from a central laboratory.

7. The new WHO guidelines for drinking-water quality should be used as the basis for standards of service to rural communities.

8. Overall responsibility for surveillance should lie with the public health authority.

9. Individual supplies should be monitored and assistance given where necessary.

10. Training must be given to personnel and it should be appropriate to the tasks to be performed and should avoid overtraining.

11. Well documented records should be kept and used for operational and planning purposes.

12. Even though the authority responsible for water supply may not be the same as that responsible for national or regional water resource planning, the primary concern must always be for potable supplies.

13. Even in rural areas all European countries should be striving to connect water supplies to individual dwellings wherever these do not at present exist.

14. In designing a system for small communities preference should be given to using the best quality sources for potable supply to reduce health risks and to minimize treatment requirements. This must be developed within the context of regional plans, while of course taking due account of cost, geography, available technical expertise and sociocultural factors.

15. Treatment methods that are simple in concept and easy to operate and that minimize power and chemical requirements should be adopted whereever possible.

16. Several alternative schemes should be studied. The plan must take account of existing supplies and consideration must be given to present and future agricultural and industrial development.

17. Before developing a new source, the possibility should be investigated of connection into an existing or planned regional system, or a system designed to serve a large nearby town.

18. Before developing a single small supply, consideration should be given to the possibility of developing a larger system to serve several communities, thus facilitating operation and quality control.

19. Pump systems inevitably require operation and maintenance, and gravity-fed supplies are preferred for rural situations even though the initial capital cost may be somewhat higher. Gravity systems should be designed so that sufficient head is provided to minimize the power requirements of the treatment process.

20. As a matter of principle, all water supply resources should be protected against pollution. This is particularly important in cases where a

source is being or is likely to be exploited for rural supplies, since the treatment of polluted raw water presents additional difficulties in rural circumstances.

21. Two kinds of source protection should be considered:

- — legislation, control and planning to limit long-term reduction in quality, together with the ability to enforce legislation;
- — the physical protection of individual systems.

22. Expert advice must always be sought when establishing the zones of protection needed for groundwater resources because of their importance as sources of water supply, the extreme difficulty of improving polluted groundwater, and the problems of water treatment under rural conditions.

23. Because surface sources are especially vulnerable to pollution, surface water intakes should, wherever possible, be located upstream of known sources of pollution and protected from damage and pollution.

24. The possibility of modifying agricultural practices should be examined in an effort to reduce the release of nitrogen compounds from fertilizers into water resources.

25. When new supplies are being planned for rural areas, due consideration should also be given to expanding the wastewater disposal facilities to cope with the increased consumption. If this is not done there is a potential danger to water resources.

26. For supplies to individual dwellings, wells should be capped and direct access to the well-head should be avoided to counter possible contamination.

27. Intermittent water supplies are not advisable because during periods of reduced pressure there is the risk of contaminated groundwater entering the system through leakage points.

28. It is not unusual for rural water supplies to be intermittent and, since there may be no practical alternative, consideration should be given to safe systems of domestic storage to avoid wasting stored water that has become contaminated.

29. Distribution and plumbing systems must be designed to prevent contamination and avoid wastage.

30. Systems should include adequate storage capacity to provide flexibility of operation and reduction in pumping capacity and to cater for sudden demands, such as fire-fighting.

31. Every effort should be made to reduce leakage and wastage, particularly in rural areas where pumping and treatment are necessary, to avoid unnecessary costs and to reduce the risk of contamination.

32. A reliable method of disinfection is advisable as an assurance of microbiological quality and safety.

33. Further effort should be devoted to simple and reliable systems of disinfection, appropriate for use in rural areas.

34. Further research is required to develop treatment systems that are suitable for use with rural water supplies, for the removal of ammonia, nitrate, colour, and tastes and odours.

RECOMMENDATIONS AT THE INTERNATIONAL LEVEL

1. Given the present rural water supply situation in the European Region, further working groups should be convened to deal in greater depth with the high priority aspects. Working groups on disinfection, on groundwater protection and on the effects of agriculture on water resource quality are particularly strongly recommended.

2. A more substantial survey of rural water supplies in the Region should be made.

3. Evaluation should be encouraged of the performance and operational success of water treatment processes used in some parts of Europe and elsewhere in the world that may merit more widespread application.

4. The collection and dissemination of information on treatment technologies for rural water supplies should be done through the World Health Organization reference and collaborating centres. The emphasis should be on disinfection.

5. All sources of documentary information should be disseminated in compatible formats so that the utility of all information is maximized.

6. Further development work on disinfectant dosing systems appropriate for rural supplies should be promoted.

7. Simple guidelines for the operation and maintenance of rural water supplies should be published.

8. Training schemes for operational personnel should be developed.

9. Further consideration should be given to appropriate technologies, advice and guidelines for the supply and treatment of water to individual properties.

Annex 1

THE ADVANTAGES AND DISADVANTAGES OF THE SIX MAIN DISINFECTION SYSTEMS

Hypochlorite tablets

Method	Calcium hypochlorite tablets are held in a device and placed in direct contact with the water.
Capabilities	Some of the devices allow dissolution of the tablets only at about constant rate, while with others dissolution is approximately proportional to flow.
Limitations	The dissolution rate is not very reproducible or steady.
Cost	Can be very cheap to install and operate.
Availability	Simple methods can be constructed very easily but proprietary devices are also available. Suitable tablets are not always easily available.
Operation	Contact methods are very simple but need regular unskilled attention.
Maintenance	Depends on the complexity of the device.
Controls	Important to inspect regularly.
Special factors	Tablets can be held in stock for emergency purposes or other occasional special uses.
Recommendation	A useful alternative when hypochlorite solution dosing is difficult to apply, especially to very small supplies serving only a few houses.

Constant rate hypochlorite solution dosing

Method	Sodium hypochlorite or calcium hypochlorite solution, diluted as required, is dosed by a drip feed arrrangement into a water storage tank.

Capabilities	The solution strength and dose rate can be set for any constant flow of water and chlorine demand.
Limitations	The dose is not automatically proportional to the water quality and flow, which may vary throughout the day, and therefore underdosing and overdosing are unavoidable. The dose can only be adjusted manually. Although there are many types of equipment for dosing hypochlorite solution, none is known to be entirely reliable. Simple safety precautions are required when handling the chemicals. Heating is required in colder climates to avoid freezing. Risk of trihalomethane formation exists if the concentration of organics in the water is high. Contact time required before reaching the nearest consumer.
Cost	Low initial cost and low chemical costs, but labour cost can be relatively high.
Availability	Equipment can be purchased or made up out of local components. Chemicals are widely available.
Operation	About twice-weekly attendance is required by reliable labour force.
Maintenance	Simple maintenance is required, but this can be carried out by the operator.
Controls	The operator must check the system at every attendance and adjust the dose to match the water quality to ensure a chlorine residual at the time.
Special factors	Reliability is poorest for reagent flows of less than about 1 litre per day. Dilution of the reagent carries a risk of scale formation, with further loss of reliability.
Recommendation	Best simple system, but a system that is proportional to flow is preferred if possible.

Proportional flow hypochlorite solution dosing

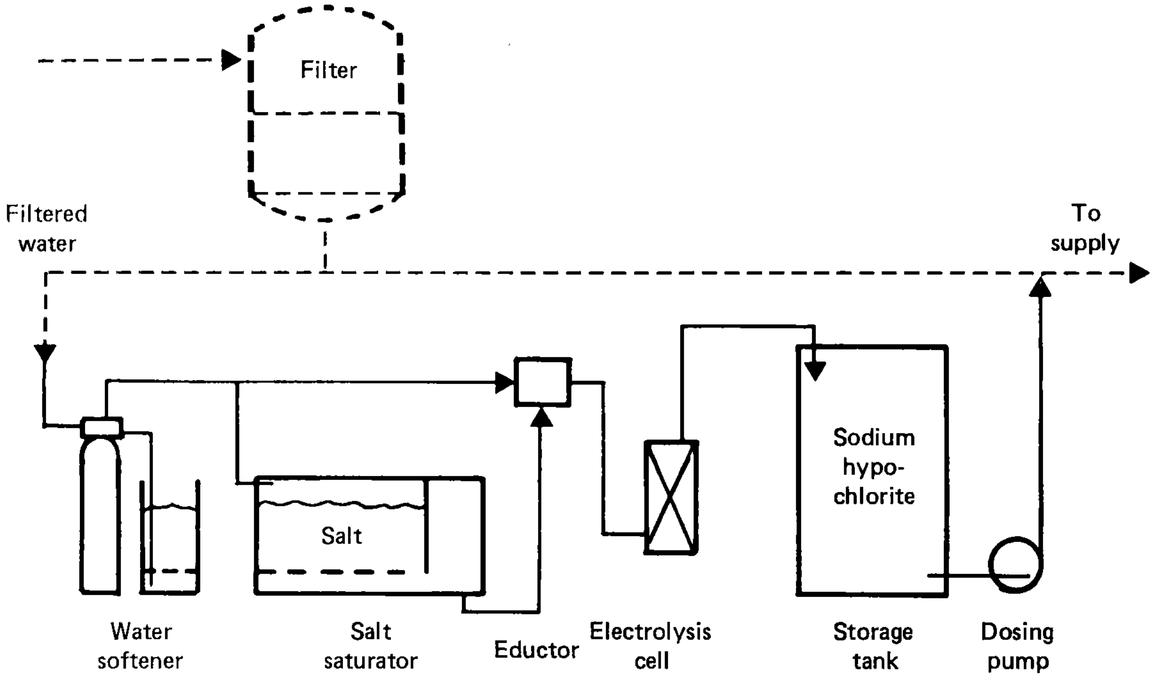
Method	Sodium hypochlorite or calcium hypochlorite solution, diluted as required, is injected into the water-main or dispensed into a tank by hydraulic or electrical pump or other device activated or controlled proportional to flow.

Capabilities	The solution strength and dose rate can be set for the chlorine demand of the water at the time of testing, and is applied in proportion to the flow.
Limitations	The dose is not automatically adjusted to the changes in water quality, and therefore underdosing and overdosing can occur if the water quality changes. Simple safety precautions are required when handling the chemicals. Heating is required in colder climates to avoid freezing. Risk of trihalomethane formation if the concentration of organics in the water is high. The choice of equipment is affected by the availability of a suitable tank, of pressure in the water-main, or of electricity. Contact time required before reaching the nearest consumer.
Cost	Moderate initial cost and low chemical cost, but labour cost can be relatively high.
Availability	Proprietary equipment is available. Spare parts may have to be held in stock. Chemicals are widely available.
Operation	About twice-weekly attendance is required by reliable labour force.
Maintenance	Some types of equipment require maintenance by semi-skilled or skilled labour.
Controls	The operator must check the equipment at every attendance and adjust the dose to match the water quality to ensure a chlorine residual at the time.
Special factors	None.
Recommendation	Preferred to constant rate dosing. Further development to permit chlorine residual control is highly desirable.

On-site production of hypochlorite

Method	Good-quality brine solution is electrolized to produce a solution of sodium hypochlorite, which is dosed as required (see Fig. 1).
Capabilities	Sodium hypochlorite is produced on-site automatically as required. The only chemical actually handled is salt.

Fig. 1. On-site production of hypochlorite



Limitations	Brine must be good quality so the make-up water may need softening. The reliability of the process is dependent on a reasonably reliable supply of electricity.
Cost	Initial cost is high, chemical cost is low but skilled attendance is needed.
Availability	The process is purchased as a package plant.
Operation	Regular attendance is needed by unskilled operators to handle salt.
Maintenance	Regular skilled maintenance is important.
Controls	It is important to monitor the quality of brine and hypochlorite to assess the need to soften the make-up water or replenish the softener and to overhaul the electrolysis cell.
Special factors	While the process is technically proven, its viability in a variety of rural situations has to be demonstrated.
Recommendation	Should only be used when there is adequate and appropriate manpower and when it is very difficult to provide chlorine by other methods. Work is needed to demonstrate the viability of the process for rural application.

Gaseous chlorine

Method	Chlorine gas from a pressurized cylinder is bubbled into a tank or deep channel or injected into a pipe through which water flows.
Capabilities	Available equipment varies from simple constant rate dosing to chlorine residual control (where electricity is available).
Limitations	Cannot be used for water flow rates less than about 1 litre per second. The equipment requires secure and lockfast housing for safety reasons. Operators must be trained in safety, and safety equipment may be necessary.

	Heating is required in colder climates to avoid freezing. Risk of trihalomethane formation if the concentration of organics in the water is high. Cylinders are heavy to handle if access is not convenient. Contact time required before reaching the nearest consumer.
Cost	Simple equipment is about twice as costly as hypochlorite doser, and better equipment is expensive.
Availability	Proprietary equipment is available. Spare parts must be held in stock. Availability of suitable cylinders must be checked.
Operation	Weekly, or more frequent, attendance is required by trained operators.
Maintenance	Must be carried out by skilled technicians.
Controls	Can be simple or sophisticated as required. Automatic alarms can be given for malfunction.
Special factors	Small cylinders of chlorine may be difficult to obtain but cylinders in stock or use should not be held too long (6 months) before returning for filling (and testing).
Recommendation	Excellent system, but not recommended unless appropriate trained or skilled labour is definitely available for maintenance.

Ultraviolet irradiation

Method	Water passes through a chamber where it is exposed to ultraviolet light. Optical surfaces can be wiped clean automatically, if required.
Capabilities	Disinfection is achieved without chemicals. No risk of trihalomethane formation. May be located near consumers.
Limitations	Produces no residual disinfection to safeguard the distribution system. Dependent on a reliable electricity supply. Effective only for waters with low turbidity and colour. Efficiency decreases as lamps age and with fouling of optical surfaces.

Cost	Not very costly to install, but electricity and lamp replacement costs are higher than the running cost of chlorination.
Availability	Proprietary equipment is available. Spare lamps must be held in stock.
Operation	Lamps and optical surfaces need checking regularly.
Maintenance	Lamps have to be replaced on failure, or routinely at expiry of nominal life.
Controls	Should be visually checked occasionally for malfunctions, but some systems give an alarm automatically if they malfunction.
Special factors	Does not produce a chemical disinfectant residual.
Recommendation	Not generally advised, but may be useful where chlorination is difficult or disinfection is precautionary rather than vital, as with very good quality groundwater or spring water.

Annex 2

THE ADVANTAGES AND DISADVANTAGES OF METHODS FOR REMOVING SUSPENDED SOLIDS

Coarse or bar screening or perforated intake

Method	Water is strained through a static frame of equidistant bars, or through a rose.
Capabilities	Prevents the passage of gross objects.
Limitations	Flow may be impeded by debris or, in cold conditions, by ice.
Cost	Very low.
Availability	Easily constructed with readily available materials.
Operation	Requires cleaning by unskilled labour force, the frequency depending on local conditions.
Maintenance	Very little maintenance needed.
Control	Visual checks by semi-skilled labour force needed according to local conditions.
Special factors	None.
Recommendation	Normally needed for all surface sources.

Fine screening

Method	Water is strained through a screen consisting of static frames or baskets, or through moving screens with automatic washing devices. The size of the aperture can be down to 30μm.
Capabilities	Removes solids according to mesh size.
Limitations	Simple screens can choke with debris or ice. Moving screens can fail owing to power supply failure, mechanical failure or overloading. Automatic screens require

	wash water. Spare parts may be difficult to obtain for proprietary equipment. The disposal of screenings may be a problem.
Cost	Low cost for static screens, but relatively high cost for moving screens.
Availability	Static screens may be constructed from local materials, but moving screens require manufactured components or may be proprietary units.
Operation	Unskilled labour force is required for routine attendance.
Maintenance	Semi-skilled labour force is required for static screens, but highly skilled labour force for automatic screens.
Controls	Automatic screens are washed continuously, or intermittently according to head loss. Visual checks are needed according to circumstances.
Special factors	None.
Recommendation	Moving and automatic screens are not recommended except where reliable power supplies and a skilled labour force are available.

Plain sedimentation

Method	Water is passed slowly and evenly through a lagoon, channel or tank to allow sediment to settle. The sediment is removed periodically by scraping, hydraulic discharge or draining down for manual removal.
Capabiltiies	Removes dense particulate matter by settlement.
Limitations	Does not remove light material, fine particles and colloids. Can be affected by wind. Algal growth may develop and affect the performance.
Cost	High initial cost, but low running cost.
Availability	Simple and easy to construct, and no special equipment or materials are needed.
Operation	Requires routine desludging by unskilled labour force.
Maintenance	Occasional structural maintenance and cleaning of inlet and outlet weirs.

Control	Visual inspection of need to remove sediment or clean weirs.
Special factors	Open to pollution unless watertight and adequately fenced or covered.
Recommendation	Useful but not essential for surface water sources unless suspended solids concentration is very high.

Infiltration

Method	Water is drawn from stream or river through its bed or banks into wells or tunnels (natural infiltration). Original material of bed or banks may be replaced by more porous material (artificial infiltration).
Capabilities	Suspended particles are removed by filtration to produce relatively clear water.
Limitations	Infiltration rates can be low especially after a long period of use with turbid river water. Cannot be used in rocky terrain.
Cost	Initial cost depends on the collection system and on whether the original bed or bank material is replaced. Very low operating cost.
Availability	Special equipment and materials generally not needed.
Operation	Very little mechanical operation involved.
Maintenance	Although maintenance will be infrequent, it will be manually intensive by unskilled labour force.
Control	Regular checks needed of infiltration rate and filtered water quality by semi-skilled labour force.
Special factors	Water passing through the ground can pick up iron and manganese. The process is underground but still needs protection from cattle and people.
Recommendation	Suitable for small remote sources if the river bed or bank conditions are appropriate.

Horizontal-flow gravel-bed filtration[a]

Method	Water is passed (< 2 metres/hour) along a tank about 12 m long, filled with graded material: coarsest (32 mm) at inlet, finest (2 mm) at outlet (see Fig. 1).
Capabilities	Suspended particles are removed by filtration.
Limitations	Particulate removal efficiency depends on initial water quality and filtration rate.
Cost	High construction cost.
Availability	Simple and easy to construct and no special equipment or materials needed.
Operation	Very little mechanical operation involved.
Maintenance	Infrequent (> 6-monthly) cleaning is manually intensive with unskilled labour force.
Control	Visual checks by semi-skilled labour force needed according to local circumstances, and removal efficiency should be monitored to assess when cleaning is required.
Special factors	None.
Recommendation	While not yet fully proven, may be very useful for small remote supplies and for upgrading simple sedimentation as pretreatment for slow sand filtration.

Slow upflow sand filtration[b]

Method	Water is filtered slowly upwards through a graded series of sand layers in the bottom of a covered storage tank. The sand is cleaned by draining down at a high rate, using some of the stored water. Inflow is controlled by a valve operated by a float in the stored water (see Fig. 2).
Capabilities	Combines filtration and storage functions.

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[a] **Trüeb, E.** Horizontal-flow gravel filters for preliminary purification of surface water especially for use in developing countries. *3R international,* **21**: 30–32 (1982).

[b] **Forsyth, H.D.** Upward flow filtration of water. *In: Proceedings of the Royal Society of Arts of Scotland,* Section A. Edinburgh, 1961, pp. 1–13.

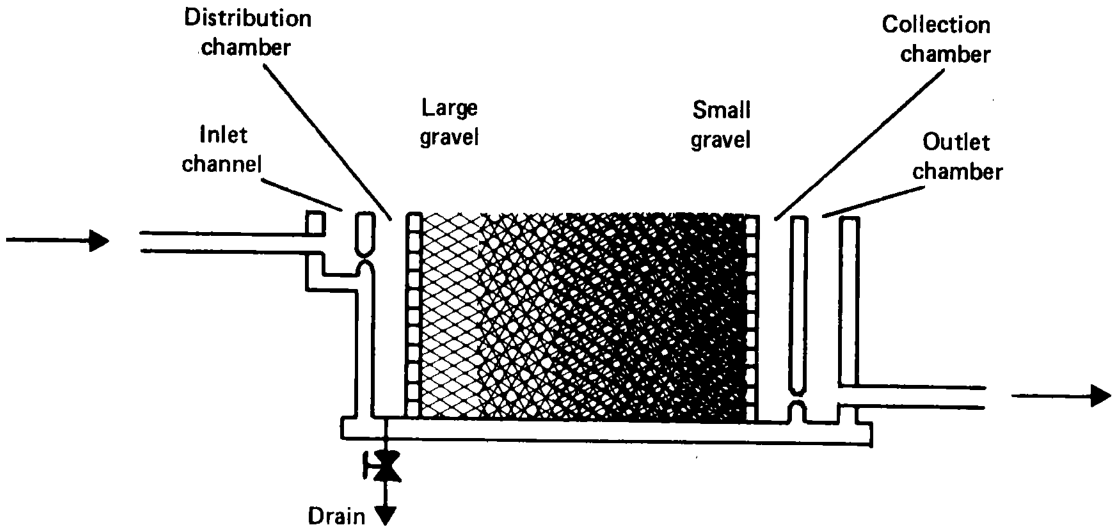
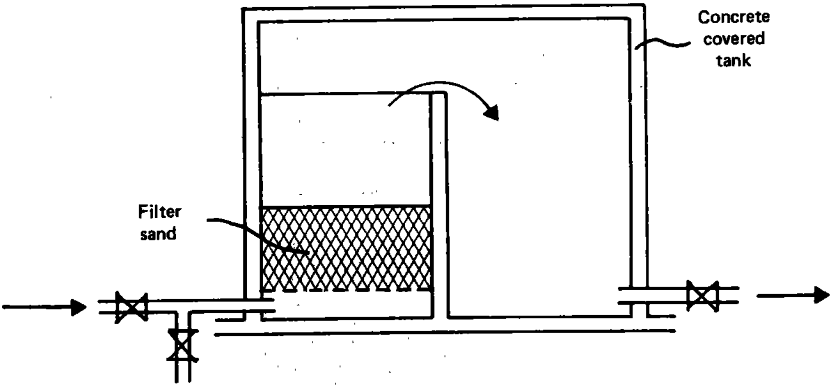


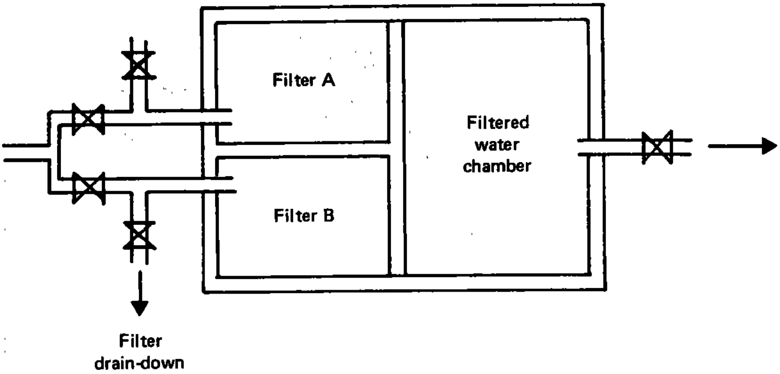
Fig. 1. Horizontal-flow gravel-bed filter

Fig. 2. Slow upflow sand filter

SECTION



PLAN



Limitations	The pipework, valving and structure require skilled construction. Washwater may require sedimentation before discharge.
Cost	High initial cost, very low operating cost.
Availability	Simple and easy to construct, but needs special float operated valve.
Operation	Periodic draining down is needed (once a week) by unskilled labour force.
Maintenance	Occasional valve and structural maintenance needed. Sand requires thorough cleaning or replacing, but only after many years' operation.
Controls	Self-regulating within design limits.
Special factors	Does not function like a slow sand filter.
Recommendation	A simple and effective filter suitable for surface water sources, but research is needed to identify optimum flow rates and sand profiles.

Slow sand filtration[a,b]

Method	Water is passed slowly (<0.3 metres per hour) downwards through sand (effective size <0.4 mm, depth >0.6 m).
Capabilities	Suspended particles are removed by filtration. If sunlight can reach the top of the filter bed then substantial biological action improves the water further. Enclosed filters can also improve the biological activity. Slow sand filters can produce water of good microbiological quality.
Limitations	Covering is necessary in very exposed sites or where freezing can be severe. Where water contains high concentrations of organic colour, colloids, silt, algae or iron, pretreatment or an alternative process is needed.

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[a] **Huisman, L. & Wood, W.E.** *Slow sand filtration.* Geneva, World Health Organization, 1974.

[b] *Slow sand filtration for community water supply in developing countries: a design and construction manual.* The Hague, The International Reference Centre for Community Water Supply, 1978 (IRC Technical Paper Series, No. 11).

Cost	High initial cost but low operating cost.
Availability	Simple to construct and does not need special materials or equipment except for filter sand and underdrainage system.
Operation	Semi-skilled labour force is needed to skim sand bed (monthly or less frequently).
Maintenance	Unskilled labour force is need to refill sand bed (annually or less frequently). Skilled labour force is required for occasional structural maintenance.
Controls	Start of filter operation needs care. Headloss must be monitored to assess the need to skim the sand bed.
Special factors	Pretreatment may be necessary. When the system works well, the disinfectant dose can be substantially reduced.
Recommendation	Suitable for treating water from surface collectors, streams and lakes, subject to limitations.

Rapid pressure filtration

Method	Water under pressure is passed downwards or upwards through a closed steel vessel containing graded sand layers. The sand is cleaned by agitation with mechanical rakes and backwashing under pressure of gravity head or pumps. The rakes are driven by hydraulic or electric power.
Capabilities	Removes solids by filtration. Efficiency depends on filtration rate, sand size and the nature of suspended solids.
Limitations	The pipework, valves and ancillaries need skilled construction. Frequent backwashing may be required if the water has high suspended solids concentration. Washwater usually requires settlement before discharge.
Cost	High cost in initial construction and attendance.
Availability	Requires manufactured components for construction and repair.
Operation	Requires frequent attendance by semi-skilled operators.

Maintenance	Mechanical maintenance by skilled labour force. Thorough overhaul, including sand cleaning, required every 10–20 years.
Controls	Operates automatically in filtration mode, but requires manual operation for backwashing. Need for backwashing must be assessed by time, headloss or filtrate quality.
Special factors	Can be upgraded by using coagulation.
Recommendation	Not suitable unless skilled maintenance is available. Upflow filter is not recommended, especially for final filtration.

Rapid gravity filtration

Method	Water is passed downwards by gravity through a bed of sand, or other suitable material, in a concrete or steel vessel. The sand is cleaned by agitation with mechanical rakes or air, and backwashed with filtered water.
Capabilities	Suspended solids are removed by filtration. Efficiency depends on filtration rate, sand size, and the nature of suspended solids.
Limitations	Involves some skilled construction. Frequent backwashing may be needed if water has high suspended solids concentration. Washwater usually requires settlement before discharge.
Cost	High cost in initial construction and attendance.
Availability	Requires manufactured components for construction and repair.
Operation	Frequent attendance needed by semi-skilled operators.
Maintenance	Mechanical maintenance by skilled labour force. Thorough overhaul, including sand cleaning, required every 10–20 years.
Controls	Operates automatically in filtration mode, but requires manual operation for backwashing. Need for backwashing must be assessed by time, headloss and filtrate quality.
Special factors	Can be upgraded by using coagulation.
Recommendation	Not suitable unless skilled maintenance and semi-skilled operators are available.

Annex 3

THE ADVANTAGES AND DISADVANTAGES OF METHODS OF CORROSION CONTROL

Alkali dosing

Method	A solution or slurry of alkali — lime, soda or sodium hydroxide — is dosed mechanically or by gravity into the water to increase its pH to the required value.
Capabilities	Can be easy to apply.
Limitations	Care is needed not to overdose highly alkaline waters and cause precipitation. It can be difficult to produce a constant pH close to neutrality in waters with low alkalinity. It is very important to ensure good mixing conditions.
Cost	Both initial and operating costs can be high depending on the choice of method or needs.
Availability	Manufactured equipment and the chemicals used are commonly available.
Operation	Regular attendance is required by a reliable labour force.
Maintenance	Simple maintenance is needed that can be done by the operator. Lime dosing can involve the most maintenance.
Controls	It is important to check performance at every attendance.
Special factors	In the simplest situation it may be possible to dose sodium hydroxide in admixture with sodium hypochlorite.
Recommendation	It is only successful with an adequate and appropriately trained labour force.

Carbonate mineral contacting

Method	Sparingly soluble alkaline material is placed in flowing water. Materials include calcium carbonate and semi-calcined dolomite. Methods include putting material in a filter, tumble contactor or baskets suspended in a tank, or feeding as a fine powder or slurry.
Capabilities	Maximum pH is limited to about pH 10 by natural considerations. Desired pH is achieved by selecting contact time or dose rate. Electrical power may not be necessary.
Limitations	Accurate pH control is not easy but is not generally intended with this treatment, though it depends on the plant design and operation and the extent to which changes in flow rate are restricted.
Cost	Need involve little or no initial cost, such as when existing filters are used. Chemical and labour costs can also be low.
Availability	Manufactured equipment need not be used. Cheap local sources of suitable mineral may exist.
Operation	Unskilled labour force is needed occasionally to handle mineral and top up filters, etc.
Maintenance	Skilled labour force may be needed for purpose-built equipment.
Controls	The effectiveness of treatment and the need to replenish material must be regularly monitored.
Special factors	Method is almost fail-safe because grossly high pH is not possible and unless no mineral is left some increase in pH is caused.
Recommendation	Very appropriate when suitable local material is available.

CO_2 desorption (air stripping)

Method	The water is sprayed or cascaded with a natural or forced flow of air in empty or packed towers or tanks.

Capabilities	The extent of CO_2 desorption depends on air and water flow rates and the choice of contacting method. The size of tower or tank can be small.
Limitations	The process necessarily involves a break of pressure in the treatment system. In hard waters calcium carbonate may precipitate if the process is too efficient. A rise in pH and dissolved oxygen in the water may lead to oxidation and the precipitation of iron, which will then need filtering. Aerator might need to be enclosed where freezing could occur.
Cost	High initial cost, operating cost can be small.
Availability	Can be simple and easy to construct, and manufactured items need not be necessary in the simplest systems.
Operation	Extent depends on system.
Maintenance	Simple maintenance is needed that can be done by the operator.
Controls	pH measurements and visual checks should be made at every attendance.
Special factors	Neutralization with alkali might be cheaper for low CO_2 concentrations ($<$20 mg of CO_2 per litre).
Recommendation	Especially attractive when there is plenty of gravity head available and it does not have to be enclosed.

Annex 4

THE ADVANTAGES AND DISADVANTAGES OF METHODS FOR REMOVING IRON

Oxidation plus filtration

Method	Fe (II) is oxidized to Fe (III) by aeration and the precipitate is removed by rapid gravity or pressure filtration. Alkali and chlorine may need to be added to enhance the oxidation rate.
Capabilities	Aeration must be effective (100% oxygen saturation) and pH high enough for a fast reaction rate. If iron concentration is very high (>2 mg of iron per litre) precipitate removal may need sedimentation before filtration.
Limitations	In exposed sites or because of freezing conditions aeration may need to be enclosed. If alkali or chlorine are also dosed then the complexity of the process is increased. The disposal of settled and filtered precipitate may involve additional attention.
Cost	High initial cost. Operating cost depends on the use of alkali and chlorine and the disposal of precipitate.
Availability	The filter needs manufactured components.
Operation	Requires frequent attendance by a semi-skilled operator, especially if alkali or chlorine are dosed and iron concentrations are very high.
Maintenance	Requires mechanical maintenance by a skilled labour force and thorough overhaul every 10–15 years.
Controls	Regular monitoring is required of filtered water quality to assess the need to adjust chemical dosing and to backwash the filter. It is preferable to dose chemicals in proportion to the flow.

Special factors	The disposal of precipitate could be a problem.
Recommendation	Not suitable unless an adequate labour force is available, otherwise find an alternative source.

Catalytic filtration

Method	Water is passed through a gravity or pressure filter containing catalytically active media. Iron and manganese dissolved in the water are oxidized and precipitated. Potassium permanganate can be used to enhance the oxidation and activate the filter media.
Capabilities	Effective at removing moderate concentrations of iron and manganese.
Limitations	Needs a little more attention than rapid gravity or pressure filtration. Filtered precipitate may need further treatment before disposal.
Cost	High cost in initial construction and attendance.
Availability	Filter needs manufactured components. Pre-activated filter media can be obtained but this is not necessary.
Operation	Requires regular attendance by a semi-skilled operator.
Maintenance	Filter needs mechanical maintenance by a skilled labour force and thorough overhaul every 10–15 years.
Controls	Regular monitoring is required of filtered water quality to check catalytic activity and the need to backwash the filter.
Special factors	The disposal of filter backwash could be a problem.
Recommendation	Suitable if an adequate labour force is available to operate and maintain the filter.

Annex 5

THE ADVANTAGES AND DISADVANTAGES OF METHODS OF CONTROLLING TASTES AND ODOURS

Absorption by granular activated carbon

Method	Water is filtered downwards through a bed of granular activated carbon (GAC). GAC can replace filter sand or be placed in its own additional filter after sand filtration.
Capabilities	Most odorous substances will be absorbed, but not all.
Limitations	Removes chlorine if dosed beforehand. High organic colour will reduce the capacity to absorb other substances. Dose cannot be adjusted.
Cost	High initial cost for filter structure and GAC. Replacement of exhausted carbon is expensive.
Availability	Manufactured filter components and GAC needed.
Operation	A semi-skilled labour force is needed for the routine backwashing of the carbon filter.
Maintenance	Mechanical maintenance is needed by a skilled labour force. GAC needs replacement occasionally (from every 6 months to 2 years or more).
Controls	Operates automatically in filtration mode but needs manual operation for backwashing. Need for backwashing must be assessed by time, headloss or filtrate quality.
Special factors	GAC stimulates the corrosion of mild steel.
Recommendation	Should only be considered when alternative techniques are inadequate, and a viable rapid gravity or pressure filtration system can be built and operated well.

Permanganate dosing

Method	Dose a solution of potassium permanganate before slow sand filtration when algae cause taste and odour. Enough contact time is needed before slow sand filter to ensure the desired effect and avoid disruption of biological activity in the filter.
Capabilities	Can oxidize some but not all odorous substances. Dose and effectiveness will depend on the presence of other easily oxidizable compounds.
Limitations	It is important to ensure that no permanganate residual enters slow sand filters.
Cost	Low initial cost. High labour cost when in use.
Availability	Simple preparation and dosing equipment, but supply of potassium permanganate may not be reliable.
Operation	A skilled labour force may be needed to support unskilled operation.
Maintenance	Simple maintenance is required that can be done by the operator.
Controls	The operator must check the system regularly and adjust the dose as necessary.
Special factors	It is important to allow contact time.
Recommendation	Simpler and cheaper alternative to GAC filtration, but viability should and can easily be tested first.

Annex 6

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Annex 7

MEMBERSHIP OF SUBGROUPS

Subgroup 1 on technology of water treatment and disinfection for all types of sources and distribution systems, appropriate for use with rural water supplies

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Subgroup 3 on organization, surveillance and personnel management and training

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[a] Participation expenses not paid by WHO.

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