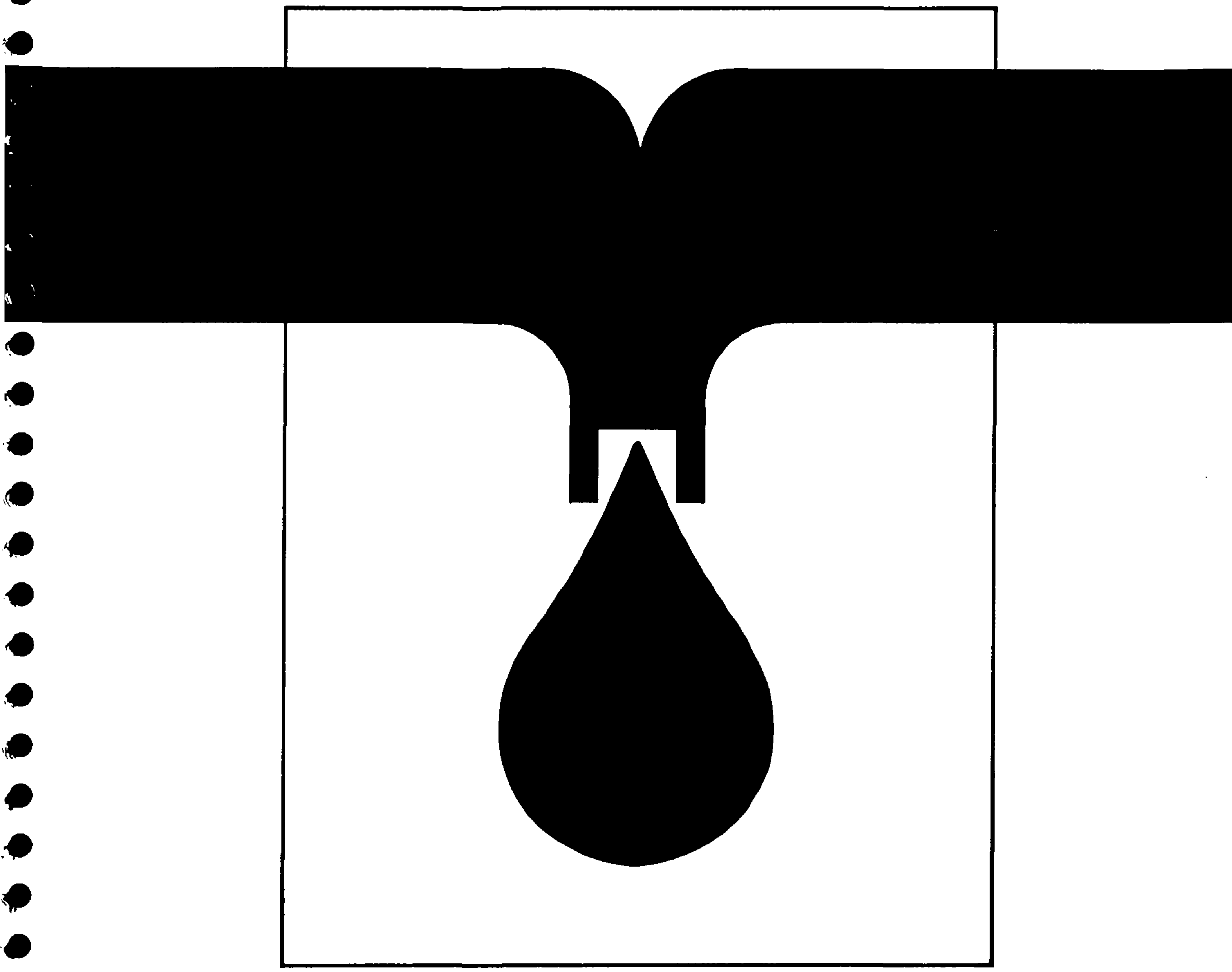
TRAINING MODULES
FOR
WATERWORKS PERSONNEL



Special Knowledge
2.2
Hygienic standards of drinking water

Foreword

Even the greatest optimists are no longer sure that the goals of the UN "International Drinking Water Supply and Sanitation Decade", set in 1977 in Mar del Plata, can be achieved by 1990. High population growth in the Third World combined with stagnating financial and personnel resources have led to modifications to the strategies in cooperation with developing countries. A reorientation process has commenced which can be characterized by the following catchwords:

- use of appropriate, simple and - if possible - low-cost technologies,
- lowering of excessively high water-supply and disposal standards,
- priority to optimal operation and maintenance, rather than new investments,
- emphasis on institution-building and human resources development.

Our training modules are an effort to translate the last two strategies into practice. Experience has shown that a standardized training system for waterworks personnel in developing countries does not meet our partners' varying individual needs. But to prepare specific documents for each new project or compile them anew from existing materials on hand cannot be justified from the economic viewpoint. We have therefore opted for a flexible system of training modules which can be combined to suit the situation and needs of the target group in each case, and thus put existing personnel in a position to optimally maintain and operate the plant.

The modules will primarily be used as guidelines and basic training aids by GTZ staff and GTZ consultants in institution-building and operation and maintenance projects. In the medium term, however, they could be used by local instructors, trainers, plant managers and operating personnel in their daily work, as check lists and working instructions.

45 modules are presently available, each covering subject-specific knowledge and skills required in individual areas of waterworks operations, preventive maintenance and repair. Different combinations of modules will be required for classroom work, exercises, and practical application, to suit in each case the type of project, size of plant and the previous qualifications and practical experience of potential users.

Practical day-to-day use will of course generate hints on how to supplement or modify the texts. In other words: this edition is by no means a finalized version. We hope to receive your critical comments on the modules so that they can be optimized over the course of time.

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It is my sincere wish that these training modules will be put to successful use and will thus support world-wide efforts in improving water supply and raising living standards.

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Title: Hygienic standards of drinking water

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0 Introduction

Hygiene is the science of the maintenance of health. The word is derived from the name of the Greek goddess of health. All research, analyses and measures resulting from these which are aimed at preventing the outbreak or spread of disease are covered by the term "hygiene".

1 General principles of hygiene

Hygiene, as the basic science of health, must consider the environment in which human beings and animals live as a whole. Observation of this environment then allows sets of rules to be drawn up, which can, when properly followed, maintain and promote general health and prevent the spread of disease. The hygienist's field of study is thus the whole area of applied natural science, taking in the findings of biologists, microbiologists, physicists, chemists, engineers and technicians, meteorologists, geologists and physiologists. One of the hygienist's tasks is to advise doctors and members of other healing professions.

Questions of hygiene arise not only in the context of water for drinking, washing and other use, but in all areas of life. Some of the main (but by no means all) sources of hygienic problems may be: housing (including workrooms), hospitals, urban sanitation, public transport, industry, nurseries, schools, clothing, personal cleanliness, food, plus wider environmental factors such as air, water and soil. All of these sources may harbour potentially harmful agents - whether of chemical or physical origin - carried by plants, micro-organisms, parasites. For this reason, when considering the standard of hygiene to be set for potable water, the importance of the total environment, with its potential effects on human and animal health, must not be forgotten.

2 Hygiene and water

Because very many micro-organisms - such as viruses, bacteria and parasites - prefer to live, or must live, in water, there is always a risk of pathogenic (disease-causing) agents being transmitted through water to human beings or animals, possibly on a large scale. The conditions that such harmful organisms need to be able to live in water vary quite widely. Amongst the influencing factors are temperature, supply of oxygen and nutrients, solar radiation, salt content, life-span, symbioses etc.

Particularly serious hygienic problems occur when water becomes contaminated by sewage containing human or animal excreta, or by industrial effluent. This is especially true of surface water, but also to a certain degree of ground water, although as a general rule fewer organisms are able to live in this. As a rule of thumb, it can be assumed that if a surface water or ground water affected by surface water has been in the ground for a period of 50 days or more, any harmful agents it might have contained will have been largely eliminated. As a general rule, such water is then again suitable for drinking.

Many diseases can be transmitted to human beings or animals through water, provided the disease-causing agent is able to live in water for a certain minimum length of time. In the past, but also on occasions in recent times, outbreaks of cholera have been caused by the presence of cholera bacteria in drinking water. Such outbreaks have often developed into severe epidemics. Typhoid and paratyphoid are diseases which today are still frequently transmitted through water. The micro-organisms responsible are Salmonella typhi or Salmonella paratyphi. Both are rod-shaped flagellated bacteria with a number of sub-groups which can transmit typhoid or paratypoid, or also, in less severe cases, diarrhoea (gastro-enteritis). In the context of disease control, mention must also be made of bacterial carriers who, without themselves being ill, continually discharge harmful micro-organisms into sewage and can thus be responsible for contaminating drinking water supplies. Leptospira and also shigellae can transmit diseases via water if they enter sewage which then contaminates water consumed by human beings. Poliomyelitis (infantile paralysis) can be transmitted by infected water and also hepatitis (inflammation of the liver) by viruses in drinking water. A number of bacteria which can live in water cause serious gastric upsets and diarrhoea, e.g. dyspepsi coli and a number of pseudomonas types; this is particularly dangerous for babies and infants.

Water can also contain amoebae which may cause amoebic dysentery, and various types of worms. This list cannot claim to be complete. The possibility of harmful agents being present in drinking water should always be taken into account if conditions at the water source, in the catchment area or at the point of distribution give grounds for suspicion. For this reason, a comprehensive hygienic analysis of the results of observations made in the locality (see below) is essential. Since the pathogenic agents themselves cannot, as a rule, be determined by analysis of the water, recourse is taken to a determination of "indicator" bacteria such as Escherichia coli, coliform bacteria, faecal streptococci, sulphite-reducing clostridia and Pseudomonas aeruginosa (cf. 4.1).

3 Hygienic standard of drinking water

To obtain water of a satisfactory hygienic standard, the best sources are ground water (wells) or spring water. Often, however, there is no alternative to using surface water - i.e. from a river or lake, or rainwater (collected in cisterns). Drinking water should always be examined regularly to establish whether it still meets the required standard. If proper analysis is not possible (e.g. in a natural disaster), all water for human consumption must be sterilized by boiling thoroughly (for at least 5 and up to 15 minutes) or by the addition of disinfectants, e.g. chlorine. Under normal circumstances, however, potable water should always be examined to ensure that it does not contain harmful agents; such an examination covering a thorough inspection of the locality, careful taking of samples and qualified analysis of these samples.

3.1 Inspection of locality

Note must be taken of the exact situation of the water source - e.g. its relative distance from human settlements, industrial sites, cultivated land etc. The character of the locality must be described, e.g. sample taken from running surface water, a lake, water hole, non-tapped spring or marsh, a tapped water outlet such as a gallery, percolation pipe or well, rain water collected in a cistern, etc. If possible, information should be given on tributaries, where appropriate, and the estimated discharge of the source, plus technical data on e.g. the type of intake structure, material of pipework, seals, pumps and other raising devices, filtration method, disinfection etc. A particularly important aspect of the assessment of the hygienic standard of water is the careful observation of any environmental factors which may have an influence on it, such as the proximity of sewage pipes or sewage farms, cultivated land or pasture, use of fertilizers or pesticides, industry, drains, refuse tips, human settlements or roads. Other questions connected with hygiene are, for instance: Is the water disinfected by chlorination, filtration or some other treatment? Does the appearance of the water and/or its surroundings give cause to suspect some secondary influence? This could be, in the case of surface water, the proximity of sewage pipes or of agricultural land, or in the case of ground water, unfavourable geological formations or inadequate distance from e.g. cesspools in housing areas or from land used for agriculture or livestock production. Observations of this kind, as comprehensive as possible, made during inspection of the locality and properly recorded and evaluated, often provide valuable help not only in reaching a properly substantiated assessment of the general hygienic standard or the water but also in reaching a preliminary opinion on its chemical composition. Inspection of the locality should further cover catchment and intake structures and, where applicable, treatment equipment; general technical condition, state of surface, seals, ventilation etc.

3.2 Appearance of the water

The colour of the water should be observed and findings recorded: e.g. is the water colourless, very slightly discoloured, slightly discoloured, strongly discoloured; together with a description of the colour, e.g. yellowish, yellowish-brown, brownish, yellowish-green. Of equal importance is the observation of the water's relative turbidity. Turbidity may be due to the presence of inorganic or organic matter (mud, ferric oxide, clay, plankton, e.g. algae, etc) in the water. An assessment of the degree of clarity, e.g. whether clear, faintly opalescent, slightly turbid, turbid, highly turbid, opaque, is helpful in reaching an opinion on the hygienic quality of the water.

Any organisms found in the water, e.g. worms, insects, rodents, plants, algae, etc. must be recorded.

Organoleptic tests carried out in the field are mainly confined to smell, since the human sense of smell is considerably more sensitive than that of taste. Water with a strong smell can often be found to contain harmful substances: e.g. sewage, or animal or vegetable matter. The intensity of the smell can be given as belonging to one of 5 categories: very slight, slight, detectable (i.e. by all users), strong (unpleasant), very strong (offensive). Other general terms can also be used to characterize the smell of a water - such as earthy, musty, mouldy, peaty, stale, putrid, fishy, metallic, smelling of manure, excreta, fish oil, seaweed, rotten eggs (hydrogen sulphide), mineral oil, tar, phenols, chlorophenols, ammonia, chlorine, soap etc. Testing by taste should be undertaken only with care; if the water has an unpleasant or offensive smell or uninviting appearance it should either not be tasted at all or not until thorough analyses have been carried out and the results evaluated.

3.3 Field tests

The temperature of the water and of the air round the source should be measured.

If possible, discharge and pumpage with drawdown (difference in water level) should be determined.

Unless the water source is a hot spring, caution is advisable if its temperature is found to be roughly equal to that of the ambient air. In such cases the water will nearly always prove to be contaminated, especially microbiologically, making its disinfection necessary. If, on the other hand, the temperature e.g. of a ground water is far below that of the air, this already gives grounds for assuming that the water has been below the ground for a considerable period of time, resulting in a normalization of its microbiological composition.

Measurements of the pH and the conductivity of the water carried out on the spot are valuable. If the water is found to be noticeably alkaline, i.e. with a pH greater than 7.5, this indicates possible contamination e.g. by industrial or domestic effluent or resulting from other human activities. Measurement of the water's conductivity gives an approximate idea of the concentrations of salts and minerals dissolved in it, whereby the value measured at approx. 20°C in µS/cm is roughly equal to the content of dissolved minerals or salts. If the appropriate apparatus is available, a measurement of the redox potential can also be undertaken. If the result is negative, this also indicates a possible organic pollution of the water. Where measuring instruments to determine the oxygen content of the water are available, this test also gives valuable information on its hygienic quality. If the water contains undissolved and suspended matter, the concentration per litre should be estimated. Should the water contain free gases, this must be recorded. An inspection of any sediments could also be undertaken on the spot.

As a general rule, it is advisable to regard as suspect all water sources where tests carried out at regular intervals produce varying results; also water sources which react with an immediately higher discharge after precipitation.

3.4 Taking and transport of samples

The basic rule is that samples should be taken in such a way as to exclude the possibility of any secondary factors influencing the sample - otherwise results are not reliably representative. The aim must be, even under field or other, possibly difficult conditions, to prevent any secondary physico-chemical, chemical, biological or microbiological influencing of the water sample by the sampler himself, the immediate area, the apparatus used or finally through subsequent transport of the sample. Any special circumstances must be recorded so that the final assessment of the water can take these into account.

3.4.1 Taking of samples for microbiological and microscopic analysis

For microbiological examination of the water, two sterile glass bottles, each with a capacity of 250 ml, with seals which prevent the escape of bacteria, should be filled under sterile conditions. Before taking the sample, the surroundings of the water outlet (e.g. tap) and the mouth of the bottle should be flamed, e.g. using a camping primus. If more extensive microbiological analyses are to be carried out, two more glass bottles each with a capacity of 1 litre should be filled in the same way. For microscopic analysis

- which is usually carried out on the spot (e.g. the obligatory test to determine the saprobic level of a water) - a 1 litre glass bottle is filled in the same way as above. The bottle must be labelled in such a way as to preclude any confusion and sent, cooled to + 4°C, as quickly as possible (within 1 day at the most) to the analytical laboratory.

If, in exceptional circumstances, no sterile vessels are available, glass bottles which have been sterilized by boiling in water may also be used. Care must then be taken when cooling the bottle and stopper to avoid re-contamination, and an appropriate note should be made on the label. If such samples have to be taken for the microbiological analysis under field conditions, it is advisable to take a number of parallel samples, so that the results of the laboratory tests can be compared.

It must be remembered that the results of microbiological analyses always depend on the care used in taking the samples!

The bottles containing the water for microbiological examination should be about 5/6 full. If the water for analysis was chlorinated, before sterilization 0.5 ml of a 0.01 normal sterile sodium thiosulphate solution must be filled into the bottle to bind the chlorine or chloramines.

When removing the stopper from the sterilized bottle, the neck of the bottle must be held pointing down and the stopper and mouth of the bottle as far away from the body as possible, to avoid any breathing or coughing onto or into the bottle or touching of its mouth with the fingers. If a sample is taken at a tap or pump, the discharge point or nozzle must be mechanically cleaned and, after turning the flow of water on and off several times, the water allowed to flow for at least 5 minutes. Then the sampling point is flamed and, after the water has been allowed to run for a further 5 minutes, the bottles filled and sealed as described above.

Wells with hand-operated pumps must be pumped off at a steady rate for at least 10 minutes before the sample is taken. Here too, the nozzle of the pump must be cleaned and it must be ensured that the pumped-off water does not return directly to the well. In dug wells and water tanks or cisterns the water can be taken from about 30 cm below the surface by means of a sterile scoop. It is also possible to fix the sterilized bottle to a rod in such a way that it can be immersed in the water and a sample correctly taken. The same method should be used when taking samples from a surface water. There are also a number of sampling devices of varying design available, which are suitable for taking samples from surface waters, dug wells or water tanks. Detailed information on the taking of samples, but also on the proper inspection of a locality, field tests and analysis can be found in "Methodensammlung zur Wasseruntersuchung" by W. Fresenius and W. Schneider GTZ 1976/77.

To avoid any alteration of the microbiological composition of samples, transport in insulated receptacles (e.g. cold boxes as used in camping) containing ice in polythene containers has proved successful.

Should it not be possible to transport the samples quickly to the analytical laboratory in this way, the microbiological analysis can also be prepared in the field (see the GTZ survey of water-testing methods), or else certain quick tests carried out to give at least a general idea of the bacteriological composition of the water (cf. Module 3.2 - Simple water-testing procedures).

3.4.2 Taking of samples for hygienic/chemical analysis

For hygienic/chemical analysis, water samples are generally taken with the aim of determining the oxidation potential, as a non-specific measure of the content of dissolved organic contaminants; e.g. by measuring the potassium permanganate or potassium dichromate consumption. For this purpose it is good practice to take the samples in 0.5 l glass bottles which have been thoroughly cleaned, and rinsed out about 5 times before filling with the water to be analysed.

To determine the ammonium ions, nitrite ions, nitrate ions and chloride ions in the water, samples can be filled into clean 0.25 or 0.5 l plastic bottles which have also been rinsed out at least 5 times with the water for analysis. As before, samples must be kept cool and reach the laboratory as quickly as possible. Should this not be possible, simple, quick methods of hygienic/chemical analysis can be applied on the spot (c.f Module 3.2 - Simple water-testing procedures).

If more extensive physico-chemical or chemical water analyses are required, the same method of taking samples should be followed and the type of bottle material, bottle size and number of bottles chosen in accordance with the object of the analysis. It should be noted that the determination of organic pollutants, especially in traces, e.g. of polycyclic aromatics or of pesticides, requires use of specially cleaned glass bottles. When taking samples for trace analysis of e.g. heavy metals, the water sample must be acidified immediately with analytical grade hydrochloric acid and/or nitric acid and this measure recorded with the other data on the label.

As a basic rule, however, the water should always be examined as soon as possible after the sample has been properly taken, so that no secondary factors can influence its composition.

4 Laboratory analyses

As in the case of examinations undertaken in the field, the extent of the laboratory analyses may also vary quite widely. Generally speaking, however, microbiological analysis would cover, as a minimum, a determination of the concentration of germs in 1 ml of water at 20°C and/or 37°C incubation temperature and 44 $\pm$ 4 hours' incubation time, plus tests for coliform bacteria and Escherichia coli in 100 ml in each case. Due to the indicator function of Escherichia coli, a general idea of the standard of the water in microbiological terms can already be gained.

The physico-chemical or chemical analyses also vary fairly widely. As a basic rule, however, the aim should always be to detect the presence in water used for drinking or washing etc. of any agents likely to have a detrimental effect on human health.

4.1 Microbiological analysis

Following the basic tests, i.e. the determination of the micro-organism concentration in 1 ml and tests for coliform bacteria and Escherichia coli in 100 ml, it will in many cases be necessary to perform a more far-reaching microbiological analysis. Since direct test for pathogenic micro-organisms are difficult and relatively complicated, the indicator microbe Escherichia coli, when detected in 100 ml of water, can be taken as a sign that the water is contaminated by human or animal excreta (faeces). Such a contamination may also indicate the presence of pathogenic agents in the water. Escherichia coli and coliform bacteria are not themselves pathogenic germs, but symbiotic organisms which are essential in the human or animal intestines, e.g. for a proper utilization of food. If, therefore, the presence of these organisms can be detected in water, it must give rise to the suspicion that together with the faeces, pathogenic intestinal bacteria may also have entered it. Further tests, e.g. for faecal streptococci in 100 ml or sulphite-reducing clostridia in 50 ml, indicate whether previous faecal influence on the water varies, since the life-span of the indictor organism Escherichia coli in water under environmental conditions is limited. In addition, in more extensive microbiological water analyses, the test for

Pseudomonas aeruginosa as potentially pathogenic microbe is now usual, also possibly tests for salmonellae, staphylococci, fungi etc.

All of these microbiological analyses must, however, be carried out in an appropriately equipped laboratory by experienced personnel. An assessment of the water carried out in the field can employ only standardized, quick procedures which, together with observation of the locality, can be used to obtain a general picture of the microbiological composition of the water.

4.2 Microscopic analysis

Since water can be made unsuitable for human consumption not only by micro-organisms or chemical pollutants, tests to detect the presence of parasites and other aquatic organisms, e.g. by microscopic methods, are also advisable. For a determination of the saprobic level of a water, microscopic-biological analyses of flora and fauna in the water are obligatory to ascertain whether or not it is suitable for human consumption. A particular source of danger here is any contact with sewage which may contain human or animal faeces, eggs and larvae of various worms or other organisms. The concentration e.g. of worm's eggs in an effluent and in a water source used for drinking purposes which is contaminated by it may vary according to the time of day, so that a true picture can only be obtained by taking a series of samples over a certain period. The relevant literature describes a number of types of worm, e.g. the various kinds of tapeworm, which can be detected by microscopic examination, as well as other live or dead plants and animals. Especial mention should be made in this context of bilharzia. In this dangerous disease, which is endemic in tropical countries, human beings are infected by the schistosome worms boring their way through the skin. (Details on the identification of tapeworms, threadworms and trematoda (flukes) can be found in L. Hallmann: Klinische Chemie und Mikroskopie, 1966, pp 124-130, or in the survey of water-testing methods published by the GTZ).

4.3 Hygienic/chemical analyses

Hygienic/chemical analyses of a water which is to be used for drinking purposes generally includes a determination of the following parameters in the laboratory, augmented by exact observation of the locality and various quick tests and measurements undertaken in the field:

Oxidation potential, as potassium permanganate consumption or with potassium dichromate, to determine the presence of dissolved organic substances, plus a quantitative determination of ammonia, nitrite, nitrate and chloride. The results of these analyses allow a first opinion to be formed on the possibility of an anthropogenic contamination of the water, especially if the findings of the inspection of the locality and smell, taste, temperature, turbidity, discoloration etc. of the water are also taken into account.

It will sometimes be necessary, however, especially in industrial or intensively cultivated areas, to extend the analysis to include other parameters. These could be, for instance, the presence of organically bound nitrogen, substances extractable with chloroform and/or carbon tetrachloride, phenols, surfactants, organic halogen compounds, phosphorus compounds, possibly pesticides and similar products and also polycyclic aromatic hydrocarbons. These tests can, however, only be carried out in a properly equipped and specialized laboratory.

5 Evaluation of results

The appraisal of the hygienic quality of a water, i.e. of the relative significance, in terms of possible health risk, of the results of microbiological, microscopic and hygienic/chemical analyses, requires an experienced specialist.

Without such expert consideration, mistakes are all too easily made. All the separate results must be considered and evaluated in the overall context of the findings. A possible risk of infection depends, for instance, not only on the type of micro-organisms or parasites found in the water, but also on their concentration. Another factor is the extent to which people are able to adapt to variations in the hygienic standard of a water. The point made above with regard to microbiological analysis also applies to the evaluation of hygienic/chemical results. If there is difficulty in interpreting the results of tests carried out in the field or in a local laboratory, the data should be submitted to an appropriately qualified and experienced hygienist for evaluation.

5.1 Local conditions and the appearance of the water

An appraisal of local conditions in terms of the possible contamination of surface, cistern or ground water requires considerable experience. Important is an exact observation of the human and animal population of the region and a consideration of the frequency of certain diseases and of any methods of treating water which may already be used. Provided local conditions are examined carefully, general conclusions on a possible contamination or relative wholesomeness of the water can always be drawn. For this reason, the importance of exact observations and measurements in the field and their evaluation in combination with the data obtained from microbiological, microscopic and hygienic/chemical analyses is again emphasized.

5.2 Results of microbiological analysis

Determining the microbe concentration in 1 ml of water at various different incubation temperatures and times can cover only such micro-organisms as grow under the chosen conditions. If it is found that the general concentration in a water is less than 100/ml, it can be concluded that the water is acceptable. Similarly, if the test for coliform bacteria and Escherichia coli in 100 ml produces a negative result, e.g. when using the membrane filter method, it can also be assumed that the water is wholesome. This conclusion rests on the indicator function of these micro-organisms (signalling the absence of pathogenic agents) as described above.

In more detailed microbiological analyses, salmonellae, pathogenic streptococci, enteroviruses and sulphite-reducing clostridia should not be detectable in the appropriate amounts of water (e.g. 250 ml). When interpreting results, however, it should always be remembered that the risk of infection depends on the number of micro-organisms ingested and that these can, if necessary, be killed through boiling or the use of disinfectant, making the water suitable for human consumption in an emergency. Appropriate recommendations should be given to consumers on the basis of the results obtained. It is, however, better if there are waterworks which can carry out the disinfection of drinking water in a controlled manner.

5.3 Results of microscopic analysis

Water to be used for drinking or washing should not be found to contain worms or worm's eggs or larvae, protozoa, snails, algae or any other foreign matter detectable by microscopic examination.

This examination may be carried out using either a residue after evaporation or, better, on the filter after membrane filtration.

5.4 Results of hygienic/chemical analysis

Certain pragmatical figures are generally used as guidelines here. Thus, for instance, a figure for the oxidation potential of a water - i.e. the sum of the oxidizable substances present in it - lower than 2 mg/l would seem acceptable.

Particular care should be taken when evaluating the ammonium ion content. In surface waters or surface-near ground water, a pronounced content of ammonium ions, i.e. a few tenths of a milligram per litre or more, is an indication of contamination through fertilizers or human or animal faeces.

There are, however, also deep waters which contain so-called geogenic ammonium, where the overall analysis shows no sign of the water being affected by human or animal activites. Thus the interpretation of the data must take the origin of the water into account.

Nitrite ions can be present in a water in connection with the oxidation of ammonium ions or the reduction of nitrate ions. Since nitrite ions can lead to diseases, especially in small children, the nitrite ion content should be kept at a low level, always below e.g. 0.1 mg/l. Nitrate ions as such are non-toxic. They point, however, to a secondary factor influencing the water, e.g. fertilizers or oxidized sewage. Maximum permissible concentrations of nitrate ions in drinking water vary quite widely from country to country. In the Federal Republic of Germany, for instance, 90 mg/l have been permissible up to now, although an EC directive will be lowering this level in future to 50 mg/l, calculated as NO_3^-. Chloride ions, although they have no direct significance in hygienic terms, when seen in the context of the other parameters can also indicate that the water is affected. A concentration of more than 400 to 600 mg of chloride ions per litre already gives the water a salty taste.

If more extensive chemical analyses are carried out, it should be noted that concentrations of heavy metals such as copper, zinc, iron, manganese, arsenic, chromium, nickel, and lead should be below 0.05 mg/l or at most 0.1 mg/l. Cadmium and mercury levels should be considerably lower than this. The fluoride content of a water has no direct hygienic signifcance. A medicinal effect can be noted only at very high concentrations, i.e. above 20 mg/l. To have any caries-preventing effect, the fluoride concentration must be about 1.5 mg/l, and higher concentrations can occasionally cause dental fluorosis.

Non-natural organic components in a potable water should always be below the level of normal perception. This is true of phenolic substances, surfactants, oils and greases and for other substances of unknown origin detectable by smell or taste.

6 Possible hygienic measures

If tests produce results which indicate an unsatisfactory hygienic standard, immediate measures may already be suggested by observation of the locality. It should be considered whether it is possible to protect the area round the water source by enclosure, or, in the case of surface water, to prevent effluent entering the upper reaches of the water course. Further, it may be necessary to clean the well, pumps, linkage, seals, filters etc. Where the surface coatings of metal or concrete structures have detiorated or are damaged, a renewal here can often result in an improvement of the hygienic standard.

The results of microbiological analyses should always be considered in the context of the chlorine dose and the filtration method used. In other words, if the microbiological findings show an unsatisfactory water quality, the chlorine dose should be increased or the filtration speed lowered, or else the filter should be cleaned or back-washed.

Frequently, knowledge of local conditions and an understanding of the connection beween analysis data and hygienic requirements will make it possible to identify simple measures which can immediately result in improvement of the hygienic standard.

Wells, pumps, conduits, pipes, tanks etc. must be cleaned and sterilized if confirmation of bacteriological contamination is found, but also at regular intervals as a routine measure.

As cleaning agents, products based on hydrochloric acid or phosphoric ester are often used. These can dissolve the deposits of e.g. iron or manganese compounds, thus making it more difficult for micro-organisms to establish themselves and reproduce. A combined cleaning process using alkaline cleaning agents together with active substances, followed by rinsing and treatment with acid preparations can also be useful. Whichever method is chosen, cleaning must always be followed by rinsing with adequate amounts of clean water, to ensure that the cleaning agents used have been fully removed and only technically unavoidable traces of them remain in the drinking water.

If disinfection of waterworks equipment is necessary, this is nearly always carried out with chlorine-containing or chlorine-eliminating solutions.

Where a plant is disinfected with chlorine solutions on a continuous basis, a chlorine dose of up to 1 mg/l is adequate. In the case of severe contamination, however, solutions must be used containing up to several 100 mg of active chlorine per litre. Frequently it is still not adequate, however, to simply leave such highly concentrated solutions to stand in the well, pump, pipe or tank system which is to be disinfected. The best results are achieved if the chlorine solution is pumped through the system. This is because many micro-organisms attach themselves to deposits in sheltered positions or form protective outer layers of slime.
As a result, the chlorine - even in very strong concentrations - may be able to kill the micro-organisms on the outside and thus sterilize the surface; but then, following consumption of the chlorine and flushing of the system, the micro-organisms from deeper layers - where they were

protected e.g. by slime secretion and the chlorine consumption this causes - re-emerge, reproduce and again contaminate the water supply system. It must be noted that even if high doses of chlorine are used, the actual chlorine amounts available at such "pockets" of bacteria are still comparatively low, and these amounts are quite quickly consumed by the organic substances. For this reason, circulation by pumping and thus a continuous supply of fresh chlorine at these points is recommended. If such pockets of micro-organisms have already formed in a drinking-water supply system, satisfactory sterilization is often extremely difficult and it may be necessary to repeat such intensive disinfection measures several times at certain intervals, with flushing operations in between.

To prevent such a situation occuring at all, extreme cleanliness should be observed. This begins with drilling the well or impounding other water sources, laying of pipes, installation of pumps and putting water-treatment plant into operation. Such plant e.g. flocculation and filtration equipment, storage tanks - must also be thoroughly cleaned with a suitable cleaning agent, treated with solutions of chlorine and finally thoroughly flushed with clean water so that as little cleaning and disinfection agent residues as possible remain in the water.

Particular attention should be paid to the coating of tank surfaces with paint or plastics, ensuring that workmanship is satisfactory and ventilation between application of each layer adequate. The surface must be completely inert with regard to the water which is afterwards filled in. Problems often occur in this context, caused e.g. by residues of solvent or lining material transferring substances to the water which then serve as nutritive media for bacteria.

Through instruction of the population, cleansing and disinfection should include the domestic sphere. It is not enough to supply water of high hygienic standard to a household if this is subsequently infected by use of contaminated bottles, pots etc. It must be recognized that cleanliness and general hygiene is just as important in the domestic sphere as in communal facilities, and that the risk of infection is already considerably less if utensils are mechanically cleaned than if residues of food, etc. are allowed to remain in them.

Supply of water of a high hygienic standard should always be aimed at, and is necessary. The usefulness of the effort involved can be considerably reduced, however, if the water becomes contaminated through the untensils subsequently used or through storage, making it possible for harmful bacteria to establish themselves and reproduce.

6.1 Conclusion

The rules of hygiene demand that a water which is used or intended to be used for drinking purposes must be palatable as regard its origin and appearance, must not contain harmful micro-organisms in any significant concentration, parasites or harmful amounts of dissolved chemicals.

It must be noted that the types and concentrations of microorganisms detected in water samples carry indicator functions which, whilst not correlating directly with a potential harmfulness of the water, do allow the expert to draw certain general conclusions on its quality. In combination with the findings of the microscopic and the hygienic/chemical ore more detailed chemical analysis, the microbiological examination allows on opinion to be formed on whether or not a water - possibly after disinfection (e.g. boiling, chlorination) is suitable for animal or human consumption.

The expert is confronted with a problem wherever he suspects, or has confirmed through analysis, that a water source is potentially harmful for human beings and/or animals, without any other source being available. In such cases, any existing water-treatment equipment will have to be adjusted either by back-washing or replacing the sand filters, by altering the depth of the sand or gravel layers, the grain size or filtration speed, or through appropriate disinfection measures, e.g. chlorination or boiling. Although the potential risk of damaging the health of humans or animals must be of first importance, emergency situations can of course occur and impose their own rules. In such cases it should be remembered that the risk of infection from bacteria at least can be considerably reduced by chlorination of the water - residual chlorine content higher than 1 mg/l - or boiling it for not less than 5 and up to 15 minutes.

Chlorination of this concentration may possibly lead to the formation of "haloforms" (trihalogen methanes). Compared with the risk of infection, however, this is of secondary importance.

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TRAINING MODULES FOR WATERWORKS PERSONNEL

List of training modules:

Basic Knowledge

- **0.1** Basic and applied arithmetic
- **0.2** Basic concepts of physics
- **0.3** Basic concepts of water chemistry
- **0.4** Basic principles of water transport
- **1.1** The function and technical composition of a watersupply system
- **1.2** Organisation and administration of waterworks

Special Knowledge

- **2.1** Engineering, building and auxiliary materials
- **2.2** Hygienic standards of drinking water
- **2.3a** Maintenance and repair of diesel engines and petrol engines
- **2.3b** Maintenance and repair of electric motors
- **2.3c** Maintenance and repair of simple driven systems
- **2.3d** Design, functioning, operation, maintenance and repair of power transmission mechanisms
- **2.3e** Maintenance and repair of pumps
- **2.3f** Maintenance and repair of blowers and compressors
- **2.3g** Design, functioning, operation, maintenance and repair of pipe fittings
- **2.3h** Design, functioning, operation, maintenance and repair of hoisting gear
- **2.3i** Maintenance and repair of electrical motor controls and protective equipment
- **2.4** Process control and instrumentation
- **2.5** Principal components of water-treatment systems (definition and description)
- **2.6** Pipe laying procedures and testing of water mains
- **2.7** General operation of water main systems
- **2.8** Construction of water supply units
- **2.9** Maintenance of water supply units Principles and general procedures
- **2.10** Industrial safety and accident prevention
- **2.11** Simple surveying and technical drawing

Special Skills

- **3.1** Basic skills in workshop technology
- **3.2** Performance of simple water analysis
- **3.3 a** Design and working principles of diesel engines and petrol engines
- **3.3 b** Design and working principles of electric motors
- **3.3 c** –
- **3.3 d** Design and working principle of power transmission mechanisms
- **3.3 e** Installation, operation, maintenance and repair of pumps
- **3.3 f** Handling, maintenance and repair of blowers and compressors
- **3.3 g** Handling, maintenance and repair of pipe fittings
- **3.3 h** Handling, maintenance and repair of hoisting gear
- **3.3 i** Servicing and maintaining electrical equipment
- **3.4** Servicing and maintaining process controls and instrumentation
- **3.5** Water-treatment systems: construction and operation of principal components: Part I - Part II
- **3.6** Pipe-laying procedures and testing of water mains
- **3.7** Inspection, maintenance and repair of water mains
- **3.8 a** Construction in concrete and masonry
- **3.8 b** Installation of appurtenances
- **3.9** Maintenance of water supply units Inspection and action guide
- **3.10** –
- **3.11** Simple surveying and drawing work

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