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SOFT WATER TREATMENT EFFICIENCY

In Poland, soft water is carried by mountain rivers and streams, and is found in impoundment lakes located in mountainous regions. The low concentrations of calcium and manganese compounds in those waters should be attributed to the geological structure of the subsoil, which is poor in sedimentary rocks. Until recently, mountain streams and rivers have been considered synonymous with purity, but now the pollution load received is showing an upward trend. The waters under study display a low alkalinity, are sufficiently oxygenated, often contain humic acids, and experience episodes of increased coloured matter concentration and turbidity. The waters additionally receive some airborne pollutants (e.g., nitrogen and sulphur compounds) which enter the water body together with precipitation. As a result, the pH of the water taken in for drinking purposes is in many instances notably lower than the value required for potable water.

1. CHARACTERIZATION OF NATURAL SOFT WATER IN THE SUDETEN REGION

In this area, water hardness falls below 100 g $CaCO_3/m^3$, so the surface waters are classified as soft. Their total alkalinity is low (ranging from 3 to 70 g $CaCO_3/m^3$) and so is the pH (which in some instances approaches 3.5), with bicarbonate hardness (alkalinity) accounting for 80–90% of total hardness. Mineralization is poor; the concentration of sulphate ions either prevails over this of chloride ions or is of the same order.

Streams and rivers flowing through boggy areas carry large amounts of humic substances, though this is not always linked with an enhanced colour intensity. There is, however, a rise (in some instances a remarkable one) in the amount of organic pollutants. Water coming from rocky areas carries small amounts of suspended solids or mineral matter. Mountain rivers and streams are also characterized by considerable bacteriological contamination, which should be attributed to the proximity of pasture land grazed by sheep, as well as to the continuing use of obsolete wastewater treat-

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ment systems located near the shelter-homes and hostels of the mountain river basin. Variations in the extent of pollution follow a seasonal pattern, the highest pollutant concentrations being measured in vernal and autumnal seasons with atmospheric precipitation.

The yield of mountain river water intakes is in most instances very poor, and the intakes themselves are difficult to access. For those reasons, use is made (wherever possible) of simplified treatment trains allowing the treatment station to be automized and the number of staff to be remarkably reduced. The water considered suitable for intake in the Szklarska Poręba region has been characterized in the table [1]. As shown by these data, the water samples collected there display a very high softness and clarity, a low mineralization level and a low pH. With their poor buffer action (if any), the waters are strongly corrosive. The waters analyzed vary in the depth of colour and the content of organic matter from very low to very high. Their physicochemical composition can be regarded as quite stable, with the episodes of increased turbidity over the periods of heavy rainfall.

Table

Physicochemical characterization of mountain soft water

Parameter	The Kwisa river	The Kamienna river	The Łomnica river	Szklarska Poręba (average values)	
				The Wysoki Kościół stream	The Kamieńczyk stream
Turbidity, NTU	0–10	0–30	0–20	0.7	0.8
Colour, g Pt/m^3	5–25	5–60	5–30	70	50
pH	4.0–6.9	3.5–7.0	4.3–7.3	5.1	5.2
Alkalinity, g $CaCO_3$/m^3	0–10	2–42	3.5–52	5	5
Total hardness, g $CaCO_3$/m^3	14.3–30.0	5.7–70	3.5–50	11	9
Total iron, g Fe/m^3	0.07–0.14	0.03–1.62	0.0–0.45	0.36	0.18
Manganese, g Mn/m^3	0.03–0.07	0	0	0.05	0.07
Ammonia, g N/m^3	0.1–0.2	0.0–1.0	0.0–1.3	0.10	0.10
COD, g O_2/m^3	2.5–8.4	1.6–18.6	1.7–9.0	14.0	10.4
TDS, g/m^3	35–90	88–265	66–215	53	43
Chlorides, g Cl^-/m^3	2–9	3–45	5–30	9.0	8.0
Sulphates, g SO_4^{2-}/m^3	8–60	13–70	9–60	7.0	5.0

In the Karkonosze region as well as in the foot-hills area of the Sudeten, many streams and rivers (e.g., the Łomnica, Kamienna or Kwisa rivers) (table) do not very much differ in their physicochemical composition [2]. The same holds for the area of the Carpathian foot-hills. In technological terms, such waters are difficult to treat since they require the adjustment of the pH, total hardness and magnesium compounds content as well as a reduction in corrosivity. What is more, some of these waters call for the reduction in the concentrations of coloured matter, organic substances and nitrogen compounds. So far, it has only been one of the nitrogen compounds, i.e., ammonia nitrogen, whose concentration has needed a slight temporary reduction. This, however, can be achieved by establishing zones of water intake protection in foot-hill areas. Riverine water in mountain areas is not exposed to serious pollution with nitrogen or iron compounds. An increased content of iron compounds occurring in oxidized form does not impair the water treatment process.

2. TREATMENT TRAINS

In technological terms, soft water treatment has never been a straightforward process, but its sophistication will increase notably when waters of very poor buffer action (or no buffer action at all) are to be treated and the treatment train requires the inclusion of chemical processes such as coagulation. When the water to be treated displays low concentrations of coloured matter and organic substances, it is sufficient to make use of rapid filtration and disinfection. In this context, the majority of treatment stations have used the two-unit processes to treat mountain river water. Problems arise during rainfall and the ensuing increase in water turbidity when the filtration process no longer suffices to remove efficiently this pollutant. The inclusion of coagulation into the treatment train helps to enhance the treatment effects, but this enhancement is often disappointing. Because of the poor buffer action of the water to be treated, there is a tendency to minimize the coagulant doses and the coagulation process carried out in filter beds (direct filtration).

If the water to be treated is rich in coloured and organic matter, the treatment train will require the inclusion of unit processes that are normally used for surface water treatment in order to enable a reduction in the content of colloidal and dissolved pollutants. Of these unit processes, coagulation seems to be best suited for the treatment of mountain river water. To provide the coagulation effect desired it is necessary to neutralize the acids that form during the hydrolysis of the coagulant. However, with waters characterized by a poor buffer action an effective neutralization is difficult to achieve. That is why soft water treatment calls for a rise in alkalinity prior to the addition of the coagulant. It is conventional to use lime or soda lye for this purpose, but this approach is linked with the risk of local overalkalization.

Technological investigations into the water of a high content of coloured matter and organic matter have revealed that the reduction in colour and COD to the values below 15 g Pt/m^3 and 5 g O_2/m^3, respectively, was attained only with an alum dose of 100 g/m^3 and a lime dose of 28 g CaO/m^3, respectively. The water treated via this route displayed a pH 8.0, a total hardness of 55 g $CaCO_3/m^3$ and a concentration of magnesium compounds amounting to 0.6 g Mg/m^3 [1].

In compliance with the decree of the Minister of Health of 19 November 2002, water hardness (especially the concentration of magnesium compounds) should be further increased. Such an increase can be achieved all the more because a satisfactory water quality (pH 8.0; colour, 5.0 g Pt/m^3; turbidity, 0.3 NTU; COD, 3.4 g O_2/m^3; total hardness, 65 g $CaCO_3/m^3$; magnesium, 0.6 g Mg/m^3, aggressive carbon dioxide being below 2 g CO_2/m^3) has been obtained with a coagulant dose of 120 g/m^3 and a lime dose of 32 g CaO/m^3. A high coagulant dose also accounts for a rise in the extent of mineralization, which is particularly advantageous to waters of a low bicarbonate hardness, as this may enhance the efficiency of pollutant removal [3]. Increased turbidity is a factor that supports water treatment when carried out in this mode; the particles contributing to water turbidity, which are natural weighting agents for the flocs, act as coagulation aid.

Research on the enhancement of coagulation efficiency in the trains for soft water treatment is focused upon the use of prehydrol-based coagulants, which notably reduces the need of alkalization. Consideration is also given to the possibility of reducing the organic matter content in soft water by coagulation carried out in an optimal pH regime, with preoxidation as a prior step [4]. Another trend in soft water treatment recommends the abandonment of the coagulation process and the inclusion of water saturation with CO_2, as well as filtration through a dolomite bed [1], [5]. The treatment train has been verified using samples of the Kwisa river water, whose composition does not very much differ from that of the mountain waters characterized in this paper. Water treatment involving a dolomite bed of a 1.2 m depth, a filtration rate of 5–15 m/h, with simultaneous CO_2 dosage ranging between 50 and 100 g CO_2/m^3, has reduced COD and coloured matter by 80% and 55%, respectively. A major advantage of using this method is the enrichment of the water with magnesium compounds, the proportion of magnesium hardness in the increment of total hardness approaching 80%. The rise in hardness and alkalinity, as well as that in the pH, is due to the reactions of carbon dioxide with the components of the dolomite bed. Investigations have shown that the inclusion of potassium permanganate oxidation into the treatment train (prior to filtration through the dolomite bed) remarkably enhances the efficiency of the water treatment process [2].

In developing countries, there is a tendency to treat surface waters carrying large amounts of suspended solids (as well as characterized by a high turbidity and coloured matter content) via a non-reagent mode. This method is based on slow filtration (0.1 m/h) preceded by horizontal roughing filtration as the pretreatment step [6], [7]. In horizontal roughing filters (HRF), water moves in horizontal flow through a three-compartment tank, where each of the tanks is packed with a sand bed of a grain size varying from 4 to 32 mm. On average, the HRF has the following parameters: length, 5 to 9 m; width, 2.2 to 5 m; bed depth, 1.5 m, and filtration rate, 0.3 to 1.5 m/h. The treatment effect, as in the case of slow filter, depends noticeably (apart from the filtering mechanism) on the microbial growth in the bed. With such a treatment train applied to highly polluted water, the number of algae decreased at least by two orders of magnitude, and so did coloured matter content (from 130 g Pt/m^3 to 17 g Pt/m^3), turbidity (from 22 NTU to 1.9 NTU) and coli bacteria counts. The filtration cycle itself took several months [6].

Investigations into the applicability of different filtering media to the HRF process have shown [7] that turbidity can be satisfactorily reduced (from approximately 150 NTU to less than 1 NTU) using a treatment train which involves the HRF process as a pretreatment step followed by slow filtration, with basaltic valley gravel, calcium carbonate and basaltic $CaCO_3$-enriched aggregates as filter media.

Involving no chemicals, the technology described above can be considered for application to the treatment of low-buffer-action water. In order to enhance the removal of organic substances, it is advisable to modify the slow filter beds by the addition of activated carbon. However, at the final stage of water treatment via the HRF and slow filters, chemical stabilization and specifically the addition of magnesium compounds becomes a must. A major disadvantage inherent in this mode is a considerable space demand – a drawback that can hardly ever be overcome in a mountainous or rocky area, if at all. There are also some minor shortcomings such as the routine operations of HRF and slow filter cleanup (they have not been automated yet and are, therefore, troublesome, time- and labour-consuming procedures) or the low-temperature-induced inhibition of the biological processes participating in this treatment mode. This seems to be the reason why now consideration is being given to the use of the HRF-slow filtration treatment train in Poland.

More promising and less troublesome is a new technology known as MIEX-DOC® [1], [8], where organic matter is removed using microporous, magnetized, anion-exchange resins. The MIEX® resin has the capability of exchanging the molecules of dissolved organic carbon for chloride ions, thus reducing the concentration of organic substances in the water with only a slight rise in the content of chlorides. A preliminary study involving the water samples of intensive colour and MIEX® resin doses which ranged between 5 and 20 dm^3/m^3 has shown that with a 5 dm^3/m^3 dose (i.e., an optimal one), the concentrations of COD and coloured matter were reduced from 10 to 2.7 g O_2/m^3 and from 50 to 5 g Pt/m^3, respectively [1]. After treatment, turbidity approached 1 NTU, total hardness remained unchanged, and the pH rose from 5.2 to 5.9. The water treated in this way still needs chemical stabilization, which is much easier to perform when most of the organic matter has been removed. What deserves special attention is the regeneration of the spent resin and, consequently, an appropriate disposal of the ensuing effluent (brine). And this consists in the recovery of the regenerating agent and its introduction into the treatment train.

3. CONCLUSIONS

The surface waters of the Sudeten region are classified as soft. With their poor buffer action (if any), they are strongly corrosive. Pollution levels vary notably from one water body to another, ranging between waters of high purity and those characterized by a high content of coloured matter and high turbidity as well as by an increased organic matter concentration.

When the soft waters to be treated require a conventional treatment train with coagulation as a unit process, their treatment may raise serious problems, which are primarily due to the chemism of the process. In this context, the attempts to develop new technologies that would enhance the efficiency of soft water treatment have become increasingly frequent. Of the technologies developed in this way, two can be regarded as promising. One of these makes use of an anion-exchange resin, the other one involves filtration through alkaline beds.

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SKUTECZNOŚĆ OCZYSZCZANIA WÓD MIĘKKICH

Z wód miękkich, uznawanych powszechnie za czyste, coraz częściej należy usuwać nie tylko mętność i barwę, ale również zanieczyszczenia organiczne. Konwencjonalne metody oczyszczania, oparte na procesach chemicznych – z uwagi na niską buforowość wód miękkich – okazują się technologicznie trudne w realizacji. Mając to na uwadze, zaproponowano wybrane ciągi procesów technologicznych, które w znacznym stopniu mogą ograniczyć procesy chemiczne, a jednocześnie zapewnią dużą skuteczność oczyszczania wody.