CHANGE IN THE HYDROPHYSICAL AND HYDROCHEMICAL CHARACTERISTICS OF NATURAL WATERS WITH MAGNETOHYDRODYNAMIC ACTIVATION

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It is shown that the effects which arise in natural waters when they flow through nonuniform magnetic fields are governed by an increase in the free gas concentration and hydrodynamic characteristics of these waters.

The magnetohydrodynamic activation of natural waters (MANW) represents a complex of physicochemical changes which occur in natural waters (NW) as they pass through magnetic fields (MF).

It was noted earlier [1] that one factor that may cause changes in NW in the event of MANW is an increase in the concentration of free gas (in the form of macro- and microbubbles) in the liquid. This article presents empirical confirmation of this hypothesis and examines the role of the hydrochemical composition of natural waters in MANW processes.

Empirical Determination of Free Gas Concentration. In connection with the fact that we found no data in the literature on determining the concentration of free gas $c_{fr.g}$ in MANW and that the methods normally used in similar studies do not make it possible to distinguish between $c_{fr.g}$ and $c_{r.g}$, we attempted to quantitatively evaluate these changes. Analysis of existing methods showed that there is no universal method, and even the better known methods are still in the stage of laboratory testing [2, 3]. We therefore used an indirect method based on determination of the gas content of the liquid from the rate of degassing of a solution under a vacuum (the Van-Slake method).

The rate of degassing through removal of gas bubbles from the liquid is several orders greater than the rate of degassing by gaseous diffusion. As a result, the initial effect of vacuum degassing is determined by the presence of free gas in the form of bubbles. Here, up to 96-98% of the dissolved gas may be released in the initial period, with the remaining gas being released over a long period of time by diffusion.

A diagram of the experimental unit is shown in Fig. 1. The experimental method is as follows. The initial water (municipal water from Vladivostok) is poured into container 1 connected with calcium chloride tube 2. The water then flows through three-pole constant electromagnet 3, valve 4, funnel 5, and cock 6 into buret 7 and vacuum device 8. A strictly determined amount of water (29.5 ml) is sampled at 20°C by lowering the level of the mercury to line A. After this, cock 6 is closed and a vacuum is created by further lowering of the mercury level by means of equalizing vessel 9. As a result, the solution boils and gas is liberated. The mercury level is then raised and the volume of the released gas is determined with the buret 7. The evacuation is repeated 10 times, each time determining the amount of gas liberated. The solution is then drained through the cock into measuring cell 10, where its pH is measured by means of a pH-350 pH meter (11). The experiment takes 5 min.

For comparison, a control sample is passed through the equipment at the same speed but with the magnetic unit (MU) turned off. All other operations are performed as described above. In all cases, degassing of the water is accelerated after MANW (Fig. 2). The greatest degassing effect is seen at a magnetic field strength $H = 2.1 \cdot 10^4$ A/m and a mean rate of flow V = 1 m/sec. The Reynolds number Re = 7500. The water flow rate was varied in the experiment from 0.3 to 1.5 m/sec by using glass tubes of different diameters in the magnetic gap. It should be noted that an appreciable change in degassing rate was seen only at Re >5000. The initial values of pH ~ 6.8-6.9 increased to 7.1-7.2 during the experiment.

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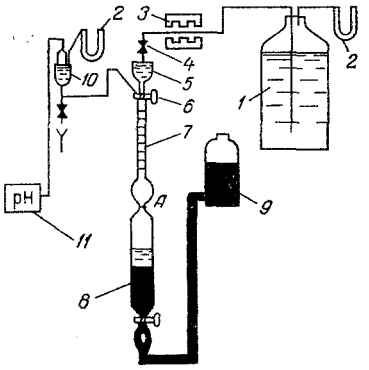


Fig. 1

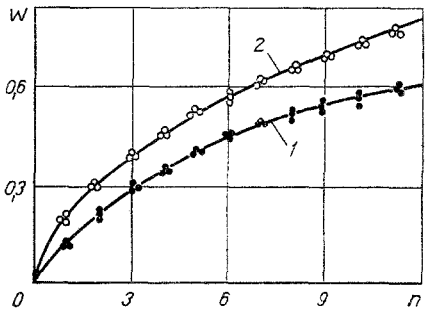


Fig. 2

Fig. 1. Set-up of experiment for determining the kinetics of gas removal from natural water with MANF.

Fig. 2. Amount of gas liberated from the water with evacuation. $W = f(n)$ ml: 1) $H = 0$; 2) $3 \cdot 10^4$ A/m; $Re = 7000$.

The empirical results obtained agree with the arguments advanced in [1] on the role of agitation of the flow and changes in the concentration of free gases in MANW.

Role of Initial Hydrochemical Characteristics. Air bubbles appearing in the moving flow play the role of intensifier in the subsequent removal of molecularity-dissolved oxygen and nitrogen from the volume of the liquid. As concerns carbon dioxide, due to its very high solubility in water, this effect will be substantially less in waters with pH < 7.5 (since its concentration is low in waters with higher pH [4, 5]).

The initial pH of natural waters also determines the effectiveness of the MANW method in increasing the effects of coagulation and reducing scale formation. The authors of [1] examined the conditions under which occurs partial dehydration of particles insoluble in the liquid, an increase in the number of these particles per unit volume and, thus, an increase in the total interfacial area. At low pH, there are no inorganic particles of $CaCO_3$, $Fe(OH)_2$, or $Fe(OH)_3$ in the volume of the liquid, while at pH > 7.5-8 the number of such particles increases sharply.

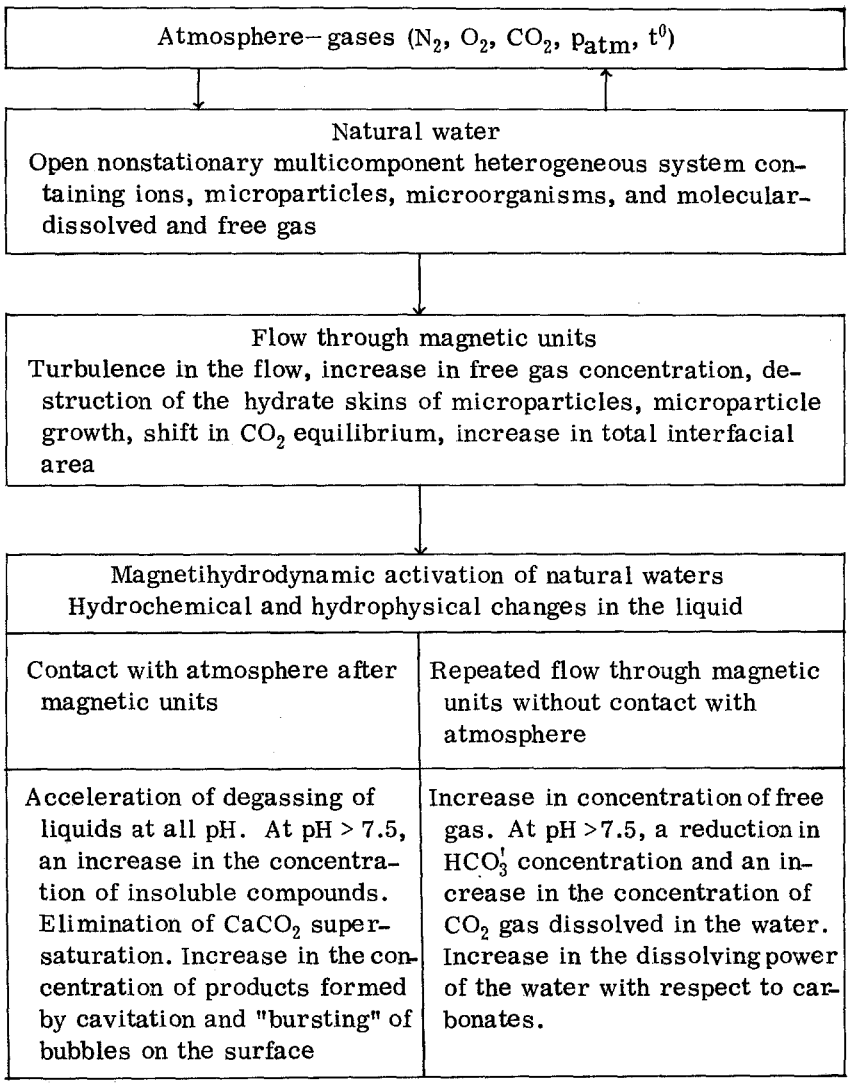
It should be noted that these requirements are to a large degree met by marine waters, where supersaturation with respect to $CaCO_3$ reaches five-ten-fold, probably as a result of stabilization of the particles by organic matter. However, for marine waters in which supersaturation with respect to $CaCO_3$ does not take place (Arctic Ocean, Baltic sea, Barents Sea), we may expect that the effects of a reduction in scale formation will be diminishes [5-7]. In water with pH > 7.5, an increase in the amount of $CaCO_3$ precipitated from solution leads to a shift in CO_2 equilibrium reaction, additional dissociation of HCO_3'' ions, and an increase in dissolved CO_2 gas in the water.

Thus, occurring parallel with the flow of natural waters through magnets are processes involving a volume increase in the number of gas-forming nuclei and, thus, an increase in vapor formation and microcrystallization. With subsequent heating of the liquid to boiling, this effect evidently becomes a sufficient condition for uniform boiling of the liquid throughout its volume, rather than merely film boiling [8]. This causes a deterioration in heat transfer from the region of the boundary layer of the liquid adjacent to the heater. In our opinion this condition is also an effective reason for the reduction in wall scale formation in heat exchangers and boilers with the use of MANW.

Contact of the Liquid with the Atmosphere in MANW. In using natural water that has been passed through magnetic units, the following three cases may be observed in practice: 1) the liquid comes into contact with the atmosphere after passing through the MU; 2) the water is used in closed circuits to which air has no access and in which the water does not come into contact with the atmosphere; 3) the set-up of the magnetic system is such that the action of the nonuniform MF on the flowing water occurs with the water in contact with the atmosphere.

Considering these cases and the initial hydrochemical parameters of the water allows us to predict differences in the character of changes in aqueous environments (Table 1). Thus, in case (1), when water having a high concentration of gas (as bubbles) enters a reservoir open to the air, then degassing of the liquid may be intensified even under normal conditions. At high temperatures or low atmospheric pressure or in the presence

TABLE 1. Change in Properties of Natural Waters with MANF



of a vacuum (in a treatment operation), these processes are further intensified. To establish an equilibrium condition through removal of micro- and macrobubbles of gas, a period of time of the order of several hours–sometimes days–is needed, since this occurs by diffusion (with a stationary liquid). The time of degassing and relaxation of properties is determined by the temperature of the liquid, the atmospheric pressure, the depth of the reservoir, the surface area of the liquid, and the initial hydrochemical characteristics.

In [1], we explored the possible additional enrichment of natural waters with products of cavitational dissociation in hydrodynamic cavitation as a result of an increase in $c_{fr.g}$ during MANW because of turbulence. Evidently, this effect may also be reinforced by the fact that the work of nucleation of small gas bubbles is changed in magnetic fields and conditions are made more favorable for bubble growth [9]. The above considerations should be supplemented by the following. When the liquid reaches an open surface, the bubbles float to the surface at rates of the order of 20-30 cm/sec, depending on their size, and the complex process of bubble "bursting" takes place at the surface, accompanied by several high-energy effects [4, 8]. These processes may serve as an additional source of the appearance of new compounds in the liquid–microparticles of films of substances which usually cover the surface of micro- and macrobubbles by virtue of their high electrical charge and adhesive properties.

In case (2) (Table 1), when the liquid flows repeatedly through the magnetic unit and does not come into contact with the atmosphere, the concentration of free gases and CO_2 may increase in a stable manner and pH may decrease in alkaline waters. This may lead to the solution of old scale, since it consists mainly of carbonates. Such scale dissolution usually takes place under similar situations.

Given condition (3), with the action of an MF on natural waters in an open system, intensive turbulence may lead to the capture of air from the atmosphere by the water.

It is useful to be able to account for the variation in the concentrations of free and dissolved gases in MANF. The presence of additional air–water interfaces in the water in essence determines not only the kinetics, but indeed the probable course of such practically important processes and boiling, cavitation, crystallization from solutions, freezing, and conduction of heat by water and is one of the factors which determine the previous history or "memory" of aqueous environments.

From a practical point of view, the above considerations expand the range of applicability of MANF, since it may be assumed that this method will also be effective when used with natural waters which are not supersaturated with respect to $CaCO_3$ and other compounds. For example, commercial trials which we performed at several plants in Vladivostok and the surrounding territory and on merchant ships using seven-pole electromagnetic units showed a reduction in scale formation with the use of sea waters in which the pH $\geq$ 8–8.3. This agrees well with the results obtained in [6]. We also observed an improvement in the operation of evaporators and deaerators on mains water with pH ~ 6.8–7.1 due to accelerated deaeration.

NOTATION

$c_{fr.g}$, concentration of free gas in the liquid (in micro- and macrobubbles); $c_{r.g}$, concentration of molecular-dissolved gas; Re, Reynolds number; p_{atm}, atmospheric pressure; W, amount of gas removed from the liquid by evacuation; n, multiplication factor of evacuation; V, liquid flow velocity, m/sec.

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