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AUTOMATIC DEVICE FOR PRODUCTION OF HYBRID COMPOSITE COMPOUNDS FOR WATER DISINFECTION

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Abstract Treatment and disinfection of water have always attracted the special attention of experts. In today's time when many challenges are present, this problem is more than actual. This paper presents scientific and professional work on a new type of automatic device for the production of active hybrid composite compounds for water disinfection. The advantages of applying our method are very successful disinfection, relatively low exploitation costs, moderate investment costs, application to all types of drinking water.

Keywords: Water treatment; automatic device; water disinfection.

1. INTRODUCTION

Chemical compounds with enhanced oxidation or reduction properties, which in principle are obtained by electrochemical reactions, are very unstable and as such require special storage conditions. In addition to ideal storage conditions (temperature, UV radiation, humidity, etc.), the half-life is from a few seconds to a few months. In cases of longer storage, spontaneous decomposition of the obtained product occurs (decrease in the concentration of the active component), so problems arise in its use or recycling. Therefore, before using such substances, the concentration of the active substance must be determined, which additionally increases the cost of the processes in which such compounds are used. Another serious problem with storage is the potential danger of uncontrolled decomposition, explosion, leakage and evaporation, which can cause serious environmental pollution.

In the industrial processes of the synthesis of dangerous substances, it is necessary that such material be produced at the place of its application and stored in appropriate tanks. In cases where smaller quantities of such materials are needed, they can be purchased and transported with all security measures to the end user. The purchase of hazardous substances (including all strong oxidizing substances) implies transport with a special vehicle and professional workforce with insurance and appropriate transport security that accompanies the procurement of hazardous substances. When storing large quantities, it is necessary to secure the facility 24 hours a day, as well as appropriate sensors that should alert the leakage of stored dangerous substances. In order to prevent excessive situations, sensors are installed that are coupled with appropriate automation that activates the spraying of the neutralizing substance (stored in the immediate vicinity) that builds a stable - less dangerous compound with it.

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The real solution to such problems would be the production of dangerous substances (chemicals) at the place of their use (in-situ) with minimal storage without storage. So it is necessary to store harmless raw materials that undergo a reaction building dangerous reactive compounds only in the range that is needed for the further process. This concept would result in a relatively safe production cycle. For such a solution, it is necessary to construct electrochemical devices whose constituent elements are reliable and easy to maintain and allow intervention on certain parts to be carried out without stopping the operation of the device.

One of the most common cases of working with dangerous chemicals is the disinfection of water in city and suburban water supply systems. Today's water disinfection stations mostly work with gas chlorination technology. Gas chlorination stations are mostly located near or even in the city centers themselves. The amount of chlorine gas stored in them can often be several tons in order to ensure a safe water disinfection process in the coming weeks or months. There are frequent cases of leakage and release of chlorine gas into the atmosphere, which poses a serious danger to humans and the ecosystem (chlorine is a military poison). In cases of using liquid chlorine compounds, it is also necessary to store them in order to ensure a smooth disinfection process over a period. All chlorine compounds are degradable and subject to spontaneous decomposition processes (the half-life is from 15 to 60 days) so that the concentration of the active substance decreases. In addition, most chlorine compounds react with compounds that are in the air, creating insoluble carbonates and bicarbonates in the reaction with carbon dioxide, and this is especially important when they are stored for a long time. Those insoluble compounds clog nozzles, ejectors, filter baskets, injection and non-return valves of dosing systems.

2. PROBLEM STATEMENT

2.1. Current State

In large water supply systems, water is usually disinfected with chlorine gas. In addition to the dangers of handling and storing chlorine gas, there are some facts that do not speak in favor of the current technology of gas chlorination of drinking water. The first danger is actually related to the current technology by which chlorine is produced. The so-called mercury technology is exclusively present here. Chlorine and hypochlorite produced by our factories, as well as many factories in the world, are obtained in reactors where mercury as a cathode is in direct contact with gaseous chlorine. In fact, in electrochemical reactors, that is, electrolyzers, vapors of mercury and gaseous chlorine go to chlorine tanks. Such chlorine with mercury admixture (90 to 228g of mercury is found per ton of chlorine) is currently widely used for gaseous chlorination of drinking water. Another, even greater danger, are incident situations during transport, storage and manipulation with chlorine. Namely, expert teams in the EU examined and proved all the dangers that are present in gaseous chlorination and dangers in the manipulation of chlorine, so that the EU has banned the use of devices for gaseous chlorination and the transport of chlorine in the territory of the Union since 1998.

Constructions of devices for in situ production of active chlorine from dilute chloride solutions have appeared in the last thirty years. One of the first devices appeared in the USA in the company "Capital Controls". The device had a flow reactor, table salt tanks and a sodium hypochlorite tank, a system for

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chemical preparation of water (softening) and a system for dosing active chlorine. The device is fully automated and relatively autonomous as far as human supervision is concerned.

At the end of the twentieth century, producers from India ("Titanium tantalum products Ltd") appeared on the world market. Electrochemical cells are equipped with cathodes made of carbon steel and anodes made of titanium activated with RuO_2 and polarized monopolarly.

Asian manufacturers also produce devices for in situ production of active chlorine after two thousand years, namely: ("IEC Fabchem limited" - India, "Water engineers" - Singapore, "WestWater Enterprises Pty Ltd." - Australia, "Prima atec Inc." - Korea, "Kalf engineering" - Singapore, "Nagpur aquatech Ltd." - India. These devices are designed with a flow reactor with storage of sodium hypochlorite. There are two types of devices one works with sea water and the other with salt water (table salt solution).

3. NEW SOLUTION

The autonomous system for obtaining softened water 2 (duplex) has the task of completely freeing the water supplying the device from calcium and magnesium ions (to remove hardness). Since it is a duplex system, it means that there is a continuous supply of softened water. Such softened water from the columns with independent automatic heads 2 enters the tank with the mixer 5 on which there is a valve Nivostat that maintains a constant level in the tank with the mixer 5. After saturation of one of them, its regeneration is automatically started while it is working - the first column softens the water. The conditioner is in container 3 (table salt). It also applies when the first column is in regeneration; the second one is active, which softens the water. The regeneration system works in four stages (column fluidization, salt injection, brine replenishment and column flushing).

The autonomous system for obtaining softened water is completely autonomous and independent both hydraulically and as regards automatic maintenance and regeneration in relation to the automatics and hydraulics of the device. In fact, it always provides a 24-hour constant supply of softened water to the device and is in no way dependent on the operation of the rest of the device. The softened water is supplied to the auxiliary tank 5 via the float valve and the tank with table salt via the electromagnetic valve 10.2 and the float valve which is in the tank itself 17. When the softened water flows through the crystal salt layer in the tank 17, it is saturated so that we get a concentrated solution of table salt of salt in the water entering the auxiliary tank with concentrated table salt 23. In the auxiliary tank 23, there is a suction basket of the dosing pumps 9.3 and 9.4, which dose the concentrated solution into the auxiliary tank for the diluted table salt solution 5.

These pumps 9.3 and 9.4 have a set constant flow ten times to a hundred times smaller than the flow of the individual pumps 9.1 and 9.2. The concentrated table salt solution is injected into the auxiliary tank 5 in which there is a mixer which mixes this solution with the softened water from the softener 2 which is added 9/10 more via the float valve and only 1/10 of the volume is added using the salt water pumps 9.3 or 9.4. Total added volume 10/10 of the dosing pump 9.1. or 9.2. are injected into the shock absorber 11, where the conductivity is continuously measured during the operation of the electrolyzer 6. From the shock absorber 11, a 0.1 to 3% solution continuously enters, where it undergoes electrolysis in the electrolyzer 6. The passage of the solution along the electrolyzer 6 leads to the

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conversion of chloride ions into active composite compounds that as an aqueous solution in a concentration of 0.1 to 1% are gravity fed into the fast chamber which is connected to the tank 14 and the automatic dosing system ADS. During electrolysis, the pneumatic space (electrolyzer 6 and tank 14) above the water line is maintained at a lower pressure than atmospheric pressure. Air from the outside (atmosphere) is also sucked in through the air line 22 and the non-return valve 21, which mixes with the separated hydrogen from the electrolyzer 6, passes through the tank 14, is sucked in by the ejector 16 and ejects into the atmosphere outside the room where the device is installed. The work of the ejector is realized by the fan 15.1 or 15.2. which are switched on alternately. Between the two fans there is a valve that closes the pressure line of the fan that is not in operation. During the operation of the electrolyzer 6, the spiral heat exchanger 20 is periodically switched on, provided that the temperature in the electrolyzer is higher than 250C. The heat exchanger is activated by turning on the electromagnetic valve 10.1, and the cooling fluid is water from the plumbing system. Since incrustations of some insoluble inorganic salts are formed in the electrolyzer 6 over a certain period of time, it is necessary after a few hundred hours of operation to carry out the acid washing process using the device 13. This part of the device has five operations that can be performed manually or automatically (emptying the electrolyzer, flow rinsing , acid cleaning, flow rinsing, batching). In the process of acid washing, the device does not produce composite compounds and that process is started only in case the tank 14 is full. From the fast chamber 25, using the automatic dosing system ADS, composite oxidizing compounds are dosed into the water supply or water treatment pipeline.

The automation of the device (Figure 1) has only one cycle of work - the cycle of the production of composite compounds. Automatic shutdown of the production cycle can be achieved in two ways: regular shutdown of the device and alarm shutdown of the device.

The regular switch-off of the device occurs only when the level of produced composite compounds reaches the upper level indicated by the level stat 8.5 in the tank with the solution of composite compounds 14. The regular switch-on of the device occurs when the level of the aqueous solution of the composite compounds falls below the level indicated by the level stat 8.3 in the tank 14. Composite the compounds are subject to the process of decomposition, ie degradation, so that if they are stored for more than a few hours, they transform into water, hypochlorous acid and sodium hypochlorite. That is why it is necessary to dose them fresh into the water we treat at the time of production, because the effect of disinfection will be several times greater than if this solvent stands and degrades into chlorine compounds - active chlorine. Therefore, immediately after the exit, a fast chamber 25 was installed, from which composite compounds are immediately dosed into the water that we want to treat with the automatic dosing system ADS.

The urgent alarm when the cycle of the production of composite compounds is turned off occurs in several cases and these cases are as follows: low pressure of the feed water detected by pressure switch 1, low level (nivostat 8.2) of the diluted NaCl solution in the auxiliary vessel with mixer 5, no flow on the salt water line which is detected by the flow indicator 7.2, the absence of flow on the line of slightly salty water which is detected by the flow indicator 7.1, too high or too low conductivity in the shock absorber 11 and it is detected by the conductivity sensor 12, the temperature in the electrolyzer is over 36°C, it is detected by the thermo probe and thermoregulator 24 , low level of air flow detected by the flow indicator 7.3, low level of crystalline salt in the table salt tank 17 detected

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by the level meter 8.7, high concentration of chlorine in the air detected by the sensor 18, high concentration of hydrogen in the air detected by the sensor 19.

Automatic activation of the device from the alarm state occurs in the following cases: If the pressure in the incoming water supply network increases above 1 bar, which is detected by the pressure switch 1, by establishing the flow in the pipeline detected by the flow sensors 7.1 and 7.2, if the conductivity parameter is in the nominal range that detects conductivity sensor 12, by switching on the air flow detection sensor 7.3, by switching off the sensor for the level of crystalline table salt 8.7, the reduction of the concentration of hydrogen or chlorine below the critical level, which is detected by the sensors for chlorine 18 and hydrogen 19, as well as if the temperature in the electrolyzer 6 drops to over 360°C so it drops below 300°C.

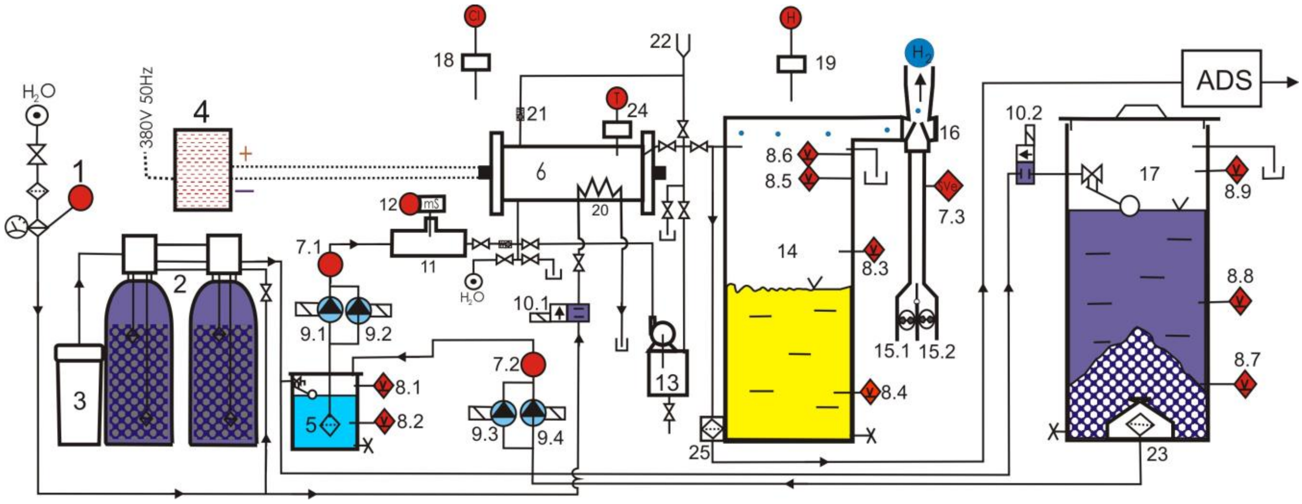

Figure 1. Scheme of the device for the production of hybrid composite compounds for water disinfection.

The warning alarm will be activated in the following cases: when the too high level of the diluted solution in NaCl is reached in the mixer auxiliary vessel 5 nivostat 8.1, the too high level of the composite compound in the tank 14 nivostat 8.9, the too high level in the table salt tank 17 nivostat 8.6 and the too low level in tank 14, level stat 8.4. All these alarms are transmitted via wired and wireless connection to the person responsible for the operation of the device on a computer or mobile phone, and the light and sound signal on the PC is activated on the device itself.

The operating cycle of the device looks like this. When a low level is reached (8.3), the device enters the operating cycle, which involves turning on the power supply 4, which supplies the electrolyzer 6 with a DC voltage of 3.4 to 48 V and a current of 20 to 800 A. At the same time when the power supply 4 is turned on, the and dosing pumps 9.1 or 9.2 as pumps 9.3 or 9.4 as well as fan 15.1 or 15.2. During the operation of the electrolyzer 6, the temperature of the electrolyzed solution increases, which is measured by the thermo probe of the thermoregulator 24. When the temperature exceeds the value of 26°C, the electromagnetic valve 10.1 opens, which lets cold water through the snake of the heat exchanger and thus cools the reaction solution, lowering its temperature below 300°C. A commercial programmable logic controller (PLC) is the main component of automation.

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During the work cycle of the electrolysis process, which takes place under atmospheric conditions (pressure 101 325 Pa and T=298 K), hydrogen is separated and ejected into the atmosphere by means of a ventilation drain. The hydrogen is drained by ventilation water outside the room where the device is located. Fans 15.1 or 15.2 push the air from the room towards the ejector, whose suction branch is installed for the tank with sodium hypochlorite 14, i.e. pneumatically connected to the electrolyzer 6, and the latter through the non-return valve 21 with the air pipe 22 that goes outside the room where the device is located (to the atmosphere). On the low-pressure branch of the ejector 16, the electrolyzer 6 and the tank 14 are pneumatically connected, where a negative pressure is created, preventing any leakage of hydrogen or chlorine at the joints, and air with separated hydrogen and chlorine is removed into the atmosphere.

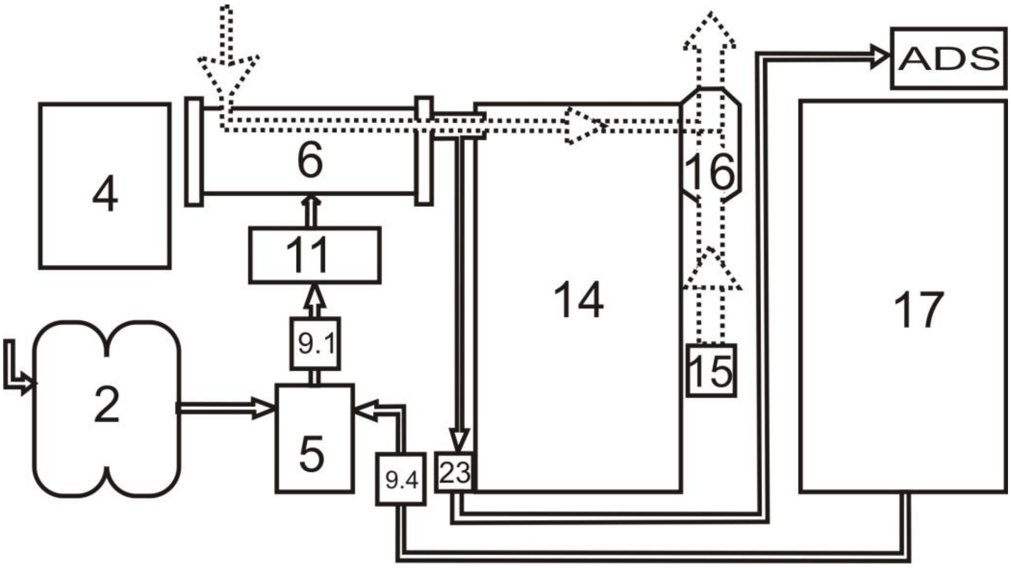

Figure 2. Block diagram of the device for the production of hybrid composite compounds for water disinfection.

Block diagram of the device for the production of hybrid composite compounds for water disinfection is given in Figure 2.

When the device's total operation of 1000 hours is completed, the condition of the so-called delayed acid washing of the electrolyzer 6 is met. This means that the device will not stop immediately after the total number of hours of operation has been reached, but another condition will have to be met, which is reaching the upper level, which is defined by level meter 8.5 in tank 14. At that moment, an information alarm (sound, light and written message) is sent to the user of the device. If the washing process of the electrolyzer 6 is not completed, it will repeat the same operation in the next cycle and after reaching the level defined by the level meter 8.5 until it is confirmed that the process of acid washing of the electrolyzer has been completed. This part of the electrolyzer washing system 13 can be done manually or automatically.

From the fast chamber 25, the solution of composite compounds is dosed into the water pipe or tank with the help of the automatic dosing system ADS. The simplest ADS system is the dosing pump itself coupled with a pump or flow meter. It is switched on if the flow meter detects the water flow and the composite compounds are dosed according to the water flow. According to the flow, the flow

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meter proportionally sends pulses to the dosing pump, which injects composite compounds into the pipeline according to the number of pulses (pulses are proportional to the water flow). In addition to the flow meter, the dosing pump can also be controlled by an amperometric electrode. In the event that the fast chamber 25 and the receiving tank 14 are emptied, the further operation of the ADS and the pump "on empty" will be stopped using the float 8.4.

The automatic operation of the device implies only the production cycle of the hybrid composite compound. If it happens that the process goes out of the designed parameters monitored by the sensors, the device is turned on and gives a sound, light and electronic - remote notification to the operator and service technician of the device. Activation of the device from the alarm state occurs in the following cases: If the pressure in the incoming water network increases above 1 bar, which is detected by the pressure switch (1), by establishing the flow in the pipeline detected by the flow sensors (7.1) and (7.2). If the conductivity parameter is in the nominal range detected by the conductivity sensor (12), the included sensors for the detection of air flow (7.3), the disconnection of the sensor for the level of crystalline kitchen salt (8.7), the reduction of the concentration of hydrogen or chlorine below the critical one detected by the sensors for chlorine (18) and hydrogen (19) as well as if the temperature in the electrolyzer drops below 300°C. Each restart implies that the automation turns on the power supply, the pump and the fan, and that the state of the sensors is not analyzed in the first 60 seconds. After the expiration of 60 seconds, the automation controls the state of the sensors and if they are all in the zone of normal operation, the device continues to work, and if they are not, the device is turned off with a notification to the operator as to why the device turned off. Only if that sensor returns to normal operation after 10 seconds, the device will automatically repeat the procedure for switching on and continuing operation.

Considering that it is a matter of slow pulse current modes, the electrolyzer (6) produces hybrid composite compounds (a mixture of several compounds based on oxygen and chlorine, sodium hypochlorite and hypochlorous acid and other radical particles capable of multiplying the effect of water disinfection or other oxidation processes). In order to prevent the degradation process of short-lived particles, a fast chamber (23) was constructed in which the suction basket of the dosing pumps is located. This fast chamber (23) enables the freshly produced hybrid composite compounds to be used as soon as possible in the disinfection process so that the spontaneous degradation of short-lived particles does not occur. In the fast chamber (25) there is a suction basket of dosing pumps from the automatic dosing system (ADS) so that they immediately inject such a fresh solution into the water we are treating. In this way, it is ensured that freshly obtained compounds with short life times (from a few seconds to a few minutes) do not decompose spontaneously, but participate in the water disinfection process.

4. CONCLUSION

The automatic device described here for the production of hybrid composite compounds for water disinfection consists of an automatic softener, dosing pumps, electrolyzer, power supply, receiving tank and tank for kitchen salt, ejector fan, fast chamber for receiving fresh composite compounds and automatic dosing system (ADS). The automation of the device has only one cycle of work - the cycle of the production of composite compounds. When the upper level in the tank is reached, the device is turned off until the automatic dosing system (ADS) consumes the stored solution to the lower level in

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the tank. Then the production cycle starts again. The obtained composite compounds have a significantly better disinfection effect, if they are used immediately. Therefore, it is necessary to dose them fresh into the water being treated at the time of production. If this solvent degrades into chlorine compounds - active chlorine - it is a bad solution. For this reason, immediately after the exit, a fast chamber was installed, from which composite compounds are immediately dosed into the water being treated using an automatic dosing system (ADS). The advantages of applying the mentioned method are very successful disinfection, relatively low exploitation costs, moderate investment costs, application to all types of drinking water.

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