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Design and implementation of fast and highly precise water magnetizer

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ABSTRACT

In the last decades, researchers have widely discussed the effects of magnetized water on many biological and industrial aspects; many studies have also examined the effects of magnetization on water physical and chemical properties and shown a slight increase in the water pH level for the drinking water after magnetizations. This article presents a new practical model to magnetize the tap drinking water with permanent, and adjustable magnets to ensure fast and precise results. A new smart system is designed and implemented to calculate the required magnetic flux density, and the exposure time based on the difference in the measured pH level of the water at the inlet and outlet pipes. Three permanent magnets, with magnetic flux densities of 500, 1000, and 1500 Gauss (G), are installed at different pipe routes, with added to a variable magnet on the main water outlet. The results show a promising prototype that is not only processing the water efficiently but also supply much data about the water properties, which can be led to more findings in this field.

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1. INTRODUCTION

Magnetized water is produced by passing water through a magnetic field [1]. Magnetized water treatment (MWT) is a relatively new technique that has environmental management applications [2]. The physical and chemical properties of water molecules result in unique characteristics by exposure to the Magnetic field. The various properties of the magnetized water (MW) is shown possible applications in different fields of environmental management and industrial applications, like scale prevention/elimination, crop yield, soil enhancement, plant growth, crop yield, water-saving, wastewater treatment, and more. The water molecules are restructured by applying the magnetic treatment, and it becomes tiny, uniform and hexagonally structured clusters easing their travel through the passageways in plant and animal cell membranes. In addition to that, the toxic agents cannot enter the MW structure. All these features make the MW a bio-friendly compound for plant and animal cells [3]. Many available magnetized water treatment devices consist of one or more permanent magnets affixed either inside or to the exterior surface of the incoming water pipe. The water is exposed to the magnetic field as it flows through the pipe between the magnets. Nevertheless, an alternative approach is to adopt an electrical current flowing through coils of wire wrapped around the water pipe to generate a variable magnetic field as in [4]. There is no doubt that the magnetic field action is causing changes in the physicochemical properties of water; researchers discussed these changes for decades [5-8].

Moreover, recently researchers are discussed; the use and application of anti-scale MWT [9], using the MW in clean water production through physical treatment [10]. The MW effectiveness on earlier accumulated iron and copper in copper pipe surfaces [11], MW Influence on early-age shrinkage cracking of concrete [12], the stability of foaming agents and foam concrete [13], concrete block pavers mechanical and durability properties [14]. The effect of the magnetized water treatment on bacterial community changes in copper and cross-linked polyethylene (or PEX) drinking water pipeline biofilms [15-17], the performance of irrigation by MW, and how it is decreasing its surface tension and increasing its volume evaporated in relation to the raw water [18]. Using the smart systems in monitoring and control is adopted by many researchers [19, 20], but [21], the presented smart system is used to monitor the quality of the water in the fish farm. An improvement in the geotechnical properties of soil bond are presented in when magnetized water adopted [22-24]. In [25], the steel fibre reinforced self-compacting concrete had been investigate, to study effect of magnetized water on the fresh and hardened properties, the results show a considerably enhancement.

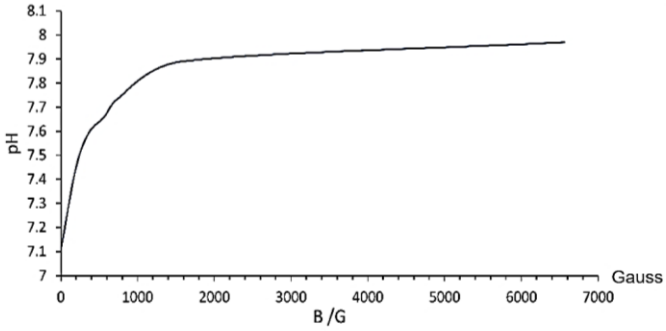
Many patents [26-29] present ideas for designing drinking water magnetizers, but this design is practically implemented with a proportional integral derivative (PID) controller that guarantee the water magnetization in the fast and precise matter. The presented system is designed to ensure the water magnetization by monitoring the changes in the water pH. It is comparing the difference between the water pH level at the water inlet pipe (WIP) and water outlet pipe (WOP) since the water pH is one of the essential parameters that indicated that the water has been magnetized. The system adopts a method to apply different levels of magnetic field strength, 500-2000 G, to the water and circulating the water until it reaches the required magnetization before it delivers for consuming. Both types of a permanent magnet, and coil, are used as required.

The results show a significant change in the water pH after magnetization and at different periods, which prove the water magnetization. In addition to a promising prototype that has open-source software, all the data are stored and exported with a timestamp for researchers and students, and more features will present in the article. To enhance the presented system, we suggest as for the future works; adding a monitoring and control system via internet of things (IoT) [30-33], or via long range (LoRa) [34, 35], also supplying the system power with photovoltaic system as in [36, 37]. In section 2, the relationship between the magnetic field and power of hydrogen (pH) will be explained, and the effect of temperature on pH will be presented in section 3, In section 4, the system technical design and implementation are discussed in detail. The system operation and strategies are presented in section 5, and results and discussion in section 6, and finally the conclusion in section 7.

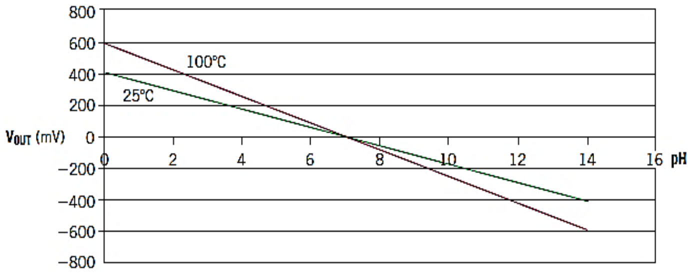
2. WATER pH LEVEL

There is a directly proportional between the applied magnetic field and the drinking water pH level at a specific range and according to the period of the process. This behaviour is caused because MW is tended to alkaline rather than acidic because of the increase of hydroxyl ions at the expense of hydrogen ions in water [38]. Figure 1 (a) shows that the exposure of water to the magnetic field slightly increased the pH of water from 7.13-7.93 by applying a magnetic field from 0-0.5 Tesla (0-5000 Gauss (G)). The pH value of water is a measure of its acidity or alkalinity; therefore, its level indicates the activity of hydrogen. When water exposed to a magnetic field, results have shown an increase in the pH by a factor of 12% by applying a magnetic field equal to 6560 G [39].

In a different matter, the water temperature has a significant effect on pH measurement [40-43], which can cause an error in the readings, due to its effect on the electrode's response (or sensitivity). This error is reasonably predictable, typically (≈0.003 pH/ºC/pH), according to the water measured temperature. These errors from changes in electrode sensitivity due to changes in temperature can be corrected by meters with temperature compensation. Figure 1 (b) shows pH readings versus the sensor output in millivolt at different temperatures. To achieve the highest accuracy, the system read the water temperature to convert the measured pH to the pH at 25°C. To do that a waterproof digital temperature sensor is used, anyway, this compensation is for monitoring only, since it did not affect the control process which depends on the difference between the pH level in WIP, WOP where the errors are cancelled out.



(a)



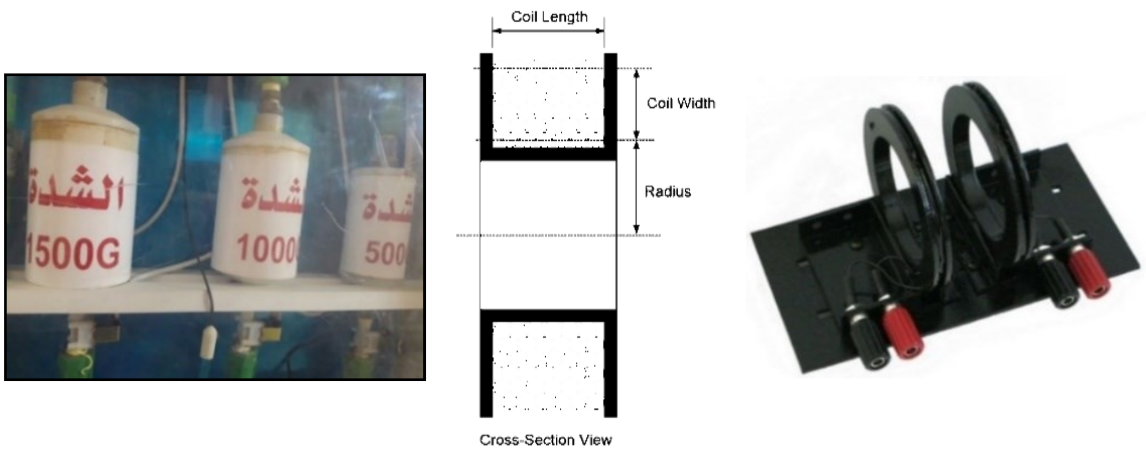
(b)

Figure 1. Water potential of hydrogen level;
(a) The relationship between the pH of the water and the magnetic field density [39],
(b) Available pH probes produce a linear slope of output voltage versus pH @ a specific temperature

3. SYSTEM DESIGN AND IMPLEMENTATION

3.1. Water magnetizer design

To magnetize the water, it is required to apply a certain amount of a magnetic field around the water pipe while the water is flowing. The applied magnetic field could be used from a permanent magnet or an electromagnetic coil. The presented system used both types to achieve any magnetic field as required. Three permanent magnets with different magnetic field strength, 500 G, 1000 G, and 1500 G, are connected in parallel, see Figure 2 (a), then in series with a variable magnetic coil. The variable magnetic coil is designed with the parameters as listed in Table 1 with the aid of [44] and shown in Figures 2 (b) and (c). The coil has 500 turns that able to supply ≈ 0-500 G. To increase the magnetizer accuracy the coil divided for 5 parts with 100 turns each, five relays are energizing these coils as required as shown in Figure 3. Table 2 presents the valves' status and the coil steps according to selected magnetic strength from 500-2000 G.



(a) (b) (c)

Figure 2. Permanent and variable magnets; (a) permanent magnets, (b) coil definitions [44], and
(c) coil case [44]

Table 1. Coil input parameters

Specifications	Value
Coil Inner Radius (mm):	20
Coil Length (mm):	100
Copper Wire Diameter with Insulation (mm):	1.53162 (Gauge:15)
Copper Wire Diameter without Insulation (mm):	1.45034 (Gauge:15)
Number of Turns:	500
Coil Current (A):	10
Frequency (kHz):	0
Distance from center (mm):	30
Core Relative Permeability, k:	0.999992
Winding Compact-Factor:	0.9
Magnetic Field (mT):	49.8991
Magnetic Field (G):	498.991
Coil Height(mm):	10.556
DC Resistance (Ohm):	0.7862
Inductance (uH):	4347.743
Minimum DC Driver Voltage Required (V):	7.862
DC Power Dissipation (W):	78.62

Table 2. The valves' status and the coil steps for the magnetic fields

Magnetic strength (G)	Coil steps	Valve 1 through (500 G)	Valve 2 through (1000 G)	Valve 3 through (1500 G)
500	0	ON	OFF	OFF
600	1	ON	OFF	OFF
700	2	ON	OFF	OFF
800	3	ON	OFF	OFF
900	4	ON	OFF	OFF
1000	0	OFF	ON	OFF
1100	1	OFF	ON	OFF
1200	2	OFF	ON	OFF
1300	3	OFF	ON	OFF
1400	4	OFF	ON	OFF
1500	0	OFF	OFF	ON
1600	1	OFF	OFF	ON
1700	2	OFF	OFF	ON
1800	3	OFF	OFF	ON
1900	4	OFF	OFF	ON
2000	5	OFF	OFF	ON

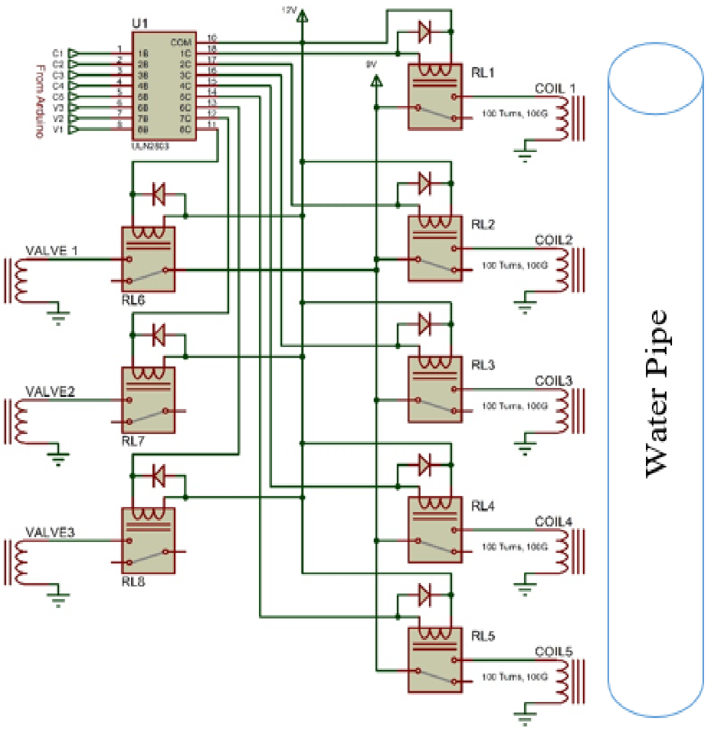


Figure 3. Relays driver circuit for coils and valves

3.2. The used sensors

- pH sensors are used to measure the water pH values in WIP and WOP as an indication for magnetizing the water. The used pH sensor is the type (65-1), which shown in Figure 4 (a), has a pH range (0-14), temperature range (0-80ºC), Zero points (7±1), and response time (<2 min).
- A temperature sensor is used by the system to measure the water temperature, water temperature readings will be used by the microcontroller to correct the errors in the pH sensors due to temperature changes. The used sensor is DS18B20, which is a waterproof digital temperature temp sensor probe, as shown in Figure 4 (b).
- A Flowmeter, type YF-S201, as shown in Figure 4 (c), is used to measure the water flow rate for two purposes. The first is for monitoring the water rate and the supplied quantity since the system can supply a specific quantity according to the user request, then shut the water. Moreover, the second reason is for control purposes, which will be explained later.
- Three electrical valves, as shown in Figure 4 (d), are used to control the water flow through the permanent magnet. These valves are drives from relays controlled by the microcontroller.

(a) (b) (c) (d)

Figure 4. System instrumentation; (a) the pH sensor, (b) the temperature sensor, (c) the used flowmeter and (d) the used electrical valves

3.3. System controller and user interface devices

The system used Mega Arduino 2560 as the main controller, its responsible on reading all the analogue and digital signals from the sensors, process all the data and correct the errors in the readings, adopt a soft PID controller for fast and accurate response, reads the user inputs from the keypads and push buttons, displays all the data on the LCD screen, and transmits all the readings and data to the computer via a USB.

3.4. System piping and instruments

As shown in Figure 5, the system's main WIP passes through a temperature sensor before the pH reading is read. This main WIP is divided into three branches to pass through different magnetic strength permanent magnets. Every branch is controlled via a solenoid valve, and the main controller is take the responsibility of energizing them. Then these branches are collected to pass through a variable magnetic coil. The strength of this coil is controlled by the main controller. The second pH sensor is measuring the pH level for the water once again at the WOP, and this reading will be used as feedback for the soft proportional integration derivative (PID) controller. The flowmeter at the WOP is used to 1) detect the flow, 2) measure the flowrate for the controller to increase or decrease the magnetic strength, and 3) calculate the total numbers of the supplied water in litres.

3.5. System operations

The basic idea of this system is to achieve a continuous correction system for the pH value at the output to ensure the magnetization of the water. This can be achieved by taking a sample reading by the water inlet pH meter as a reference reading then take another sample at the WOP to measure the difference between the input and output water pH. Another important factor is the temperature of the water; this factor effect on the pH reading linearly as the temperature increase, so a temperature sensor has been added for correcting the pH readings.

To manage all these signals, monitor them and control the coil current. An Arduino Mega Board type (Mega 2560) is used for reading the pH readings and temperature by connecting the sensors to the Arduino Board inputs and connect the magnetic coil and monitor for the outputs. The system processing flowchart is shown in Figure 6; it is also showing some of the system features which conclude as follows:

- Adapt a soft PID to manage the water pH fast and precisely.
- Correct the pH reading according to the water temperature.
- Display, store, and transmit all the reading and data with a timestamp.

– Control the water piping routes and coil steps to ensure supplying the exact amount of the magnetic strength.
– Supply the required water quantity according to the user needs.
– Sensing the flow allows the controller to save power when there is no flow or no water.
– The controller allows the user to run the system in manual mode, or automatic mode. In manual mode, the user can set the required magnetic strength manually.
– The system design to study the water properties under different conditions, this makes the system can be adopted by researchers to make more studies in this field.

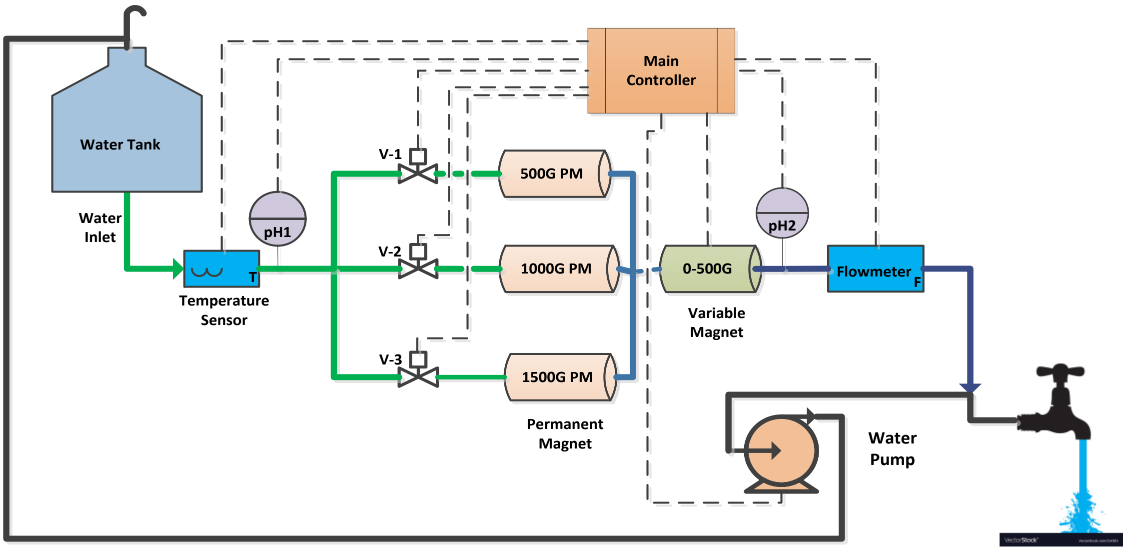


Figure 5. Piping and instruments diagram

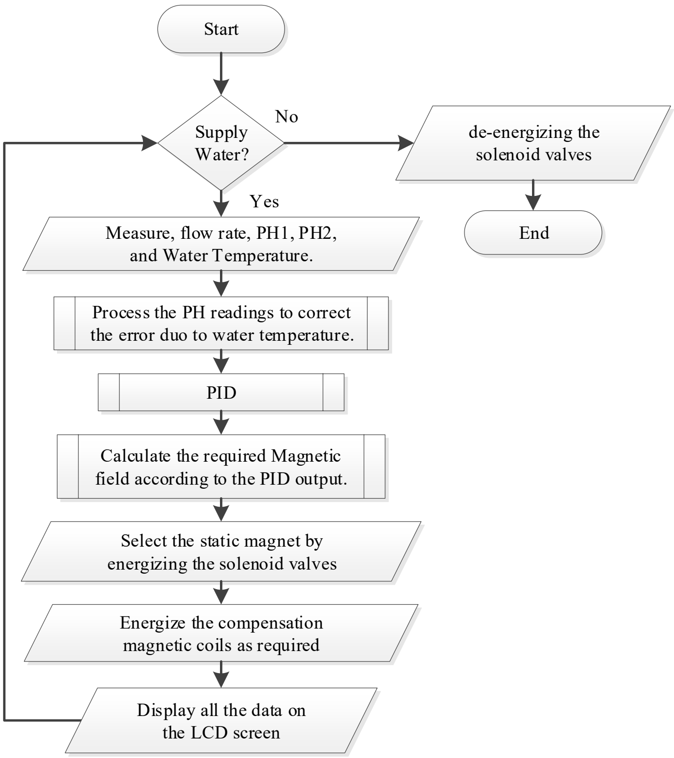


Figure 6. The System processing flowchart

4. RESULTS AND DISCUSSION

The system was designed and implemented, as shown in Figure 7. The water is circulated for twenty hours through each of the fixed magnetizers (500 G, 1000 G, and 1500 G), then the PID controller is energized. The water is changed after each experiment, and the water temperature is guaranteed at 20ºC. Two modes for the operation are adopted, manual mode and automatic mode. In the manual mode, the user can manually select any magnetic strength by pressing its button; an indicator light will be lit for indication. This mode is useful for researchers and students, and we use it to calculate the system efficiency. In the automatic mode, the system will do all the calculations and process the water as required to ensure the magnetization.

The result in Figure 8 shows that the settling times (ST) to magnetize the water, while the pH level at the inlet was 7.2 and the setpoint level for the water to deliver is 7.3, were (12h @500 G), (8h @1000 G), (6h@1500 G), and (4h @PID mode). The results also show a low steady-state error when the PID system controlling the magnetization because it is controlling the valves of the magnetizers and keeps a small amount of magnetization by the coil to compensate for the error automatically. Table 3 shows the mean error (ME) and the mean squared error (MSE) for the testing results. MSE shows a significant improvement in the system response through the testing time.

Figure 7. The final system structure

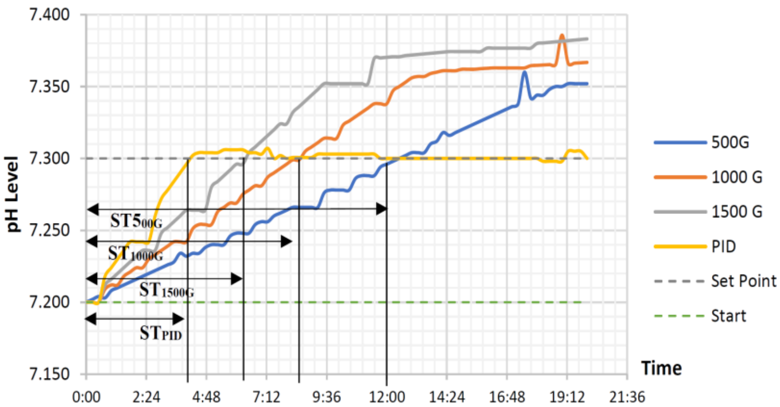


Figure 8. The pH level for the water vs time

Table 3. Mean error and the mean squared error for the system

	500 G	1000 G	1500 G	PID
Mean Error	0.020728	-0.006848	-0.024999	0.010399
Mean Squared Error	0.002625	0.003148	0.004039	0.000848

5. CONCLUSION

In this article, it was shown a design and implementation of a system that able to magnetize the water fast and precisely with the aid of a PID controller. The presented system is promising and cost-efficient. It also used open-source software, which leaves room for future development, and it will be a useful tool for the developer and researchers since it is produced continuously in an excel file for all the measured data with a timestamp. Two modes of the operations are presented, which ensure the usage of the device for researchers and students.

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