

Development of a rainwater harvesting system in a country house

The project team:

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The project relevance

At least 100 liters of clean water a day is required for the normal life of one person in a country house. Water is used directly, both in the house itself (bathroom, washing machines, dishwashers, etc.), and for irrigating plants in the garden or vegetable garden. One of the sources of clean water in a country house is rainwater.

Rainwater is rich in minerals and practically does not contain hardness salts: this promotes better assimilation by plants (including trees), prevents the appearance of white salt deposits covering the leaf surface, clogging the stomata through which respiration of plants occurs. Rainwater is much softer, often even cleaner than tap water. Such water has a beneficial effect on skin and hair, increasing the service life of household appliances.

The main difficulty in using rainwater in a country house is the correct collection and storage. The issue of developing specialized engineering systems for solving these problems is still relevant.

The project is dedicated to developing a specialized engineering system capable of increasing the efficiency of collecting, storing and using rainwater in a country house (see Fig. 1).

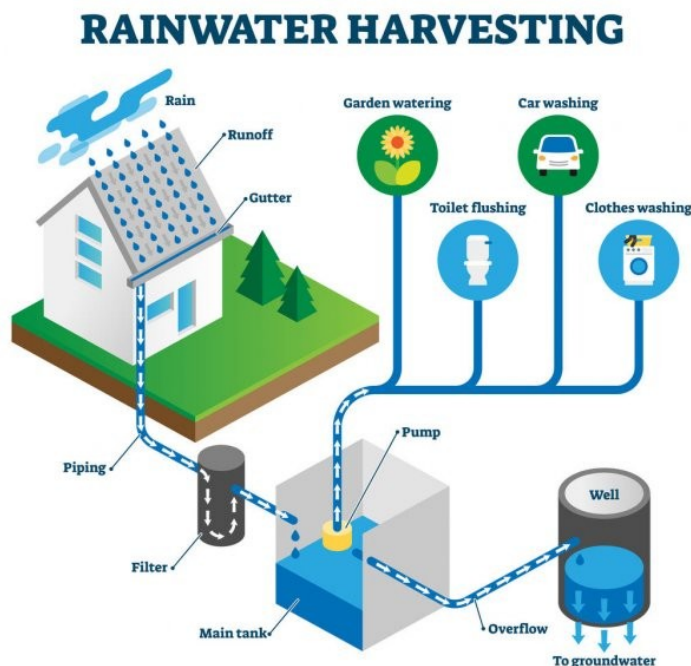


Fig.1. The project illustration

Acid rain is especially dangerous for collection, storage and usage systems, since water vapor reacts with harmful substances (containing sulfuric and nitric acids) in the atmosphere. Large cities with many manufactories face the problem of acid rain. Any pollution of the environment negatively affects the quality of rainwater. Consequently, it is necessary to use specialized rainwater treatment systems.

The water collection system plays an important role in protecting the foundation of buildings and basements from excess moisture. The increased humidity of the environment

accelerates the process of self-destruction, cracks appear. In the case of water collection, the problems described above are leveled, and the durability of buildings increases. The humidity in the basement is reduced which allows storing various types of materials that are prone to corrosion.

The tank can be used as a conventional storage facility not only for rainwater. Very often in rural areas there is insufficient water pressure, and sometimes even no water pressure at all. This is due to the huge number of consumers, whose number increases by the middle of the day. Reserve stocks will provide the country house with a stable water supply, since the water can be replenished at night or early in the morning when water consumption in other countryside areas is minimized.

The project aim and objectives:

Aim of the project: to increase the efficiency of collecting, storing and using rainwater in a country house.

The project objectives:

1. Developing the collection subsystem.
2. Developing the filtration subsystem.
3. Developing the storage subsystem.
4. Developing the pumping subsystem.
5. Developing the control subsystem

The efficiency will be increased by:

- Using rainwater for irrigation of the site;
- Using rainwater in the house for domestic needs;
- Using the tank to stabilize the water supply during the day;
- Protecting basements and foundations of buildings from excess moisture;
- Reducing the consumption of fresh water and slowing down the development of environmental problems;
- Partially reducing the costs of water supply.

The project practical relevance:

1. Increasing the service life of the water supply/drainage system, household appliances that use water (washing machines, dishwashers, etc.).
2. Increasing productivity of crops due to the use of rainwater for irrigation instead of tap water (rainwater is a natural catalyst for plant growth thanks to a number of properties).
3. Using the collected rainwater in the heating system.
4. Preserving the foundation and basements of a country house by preventing excess moisture from entering.
5. Using the storage subsystem for providing uninterrupted water supply (in case when there is no tap water).

The project implementation plan:

The final system under development includes several subsystems:

- Collection subsystem (roof, gutter and other means for collecting water);
- Subsystem of rough filtration (protective mesh for the gutter);
- Subsystem of soft filtration (means of main filtration of rainwater);
- Storage subsystem (rainwater storage tank);
- Pumping subsystem (electric pump for pumping water);
- Control subsystem (controller, liquid level sensor, solenoid valves).

Collection subsystem. It is optimal to collect rainwater from roof gutters and other angled surfaces. Before installing the system, it is important to make sure that the roof covering does not contain asbestos or lead: in this case, harmful substances will inevitably enter the water. The most suitable roofing materials are galvanized metals, ceramic or sand-cement tiles (Fig. 2). You should also make sure that the angle of the roof covering is more than ten degrees: microorganisms grow quickly on flat roofs.

The gutter and pipes should also be galvanized. The choice of galvanized materials is due to corrosion resistance (which, in addition to low toxicity, significantly increases the service life), as well as a relatively low price.

<p>galvanized coating</p>  <p>safely</p>	<p>asbestos coating</p>  <p>dangerous</p>
<p>cement-sand coating</p>  <p>safely</p>	<p>lead coating</p>  <p>dangerous</p>

Fig. 2. – Types of roof covering

Filtration subsystem. Depending on weather conditions and location characteristics, various types of debris can enter the system - leaves, dust, plastic bags, etc. In addition, rainwater has an ambiguous chemical composition. It does not contain salts of alkaline earth metals, iron, hydrogen sulfide, pesticides. But due to air pollution, it may contain other, most dangerous substances: carbon monoxide, sulfur and nitrogen oxide, or household dust.

Consequently, a multi-level system of rough and soft filtration is required, capable of purifying water from both large and dusty debris, as well as from harmful chemical components.

The protective mesh is a first level filter and is used to prevent large debris from entering the collection system; it is installed directly above the gutter (Fig. 3).



Fig. 3. – Primary filter in the form of protective mesh

Leaf separators and rough filters should be used as a second level filter to get rid of any debris left before the water enters the storage tank (Fig. 4).

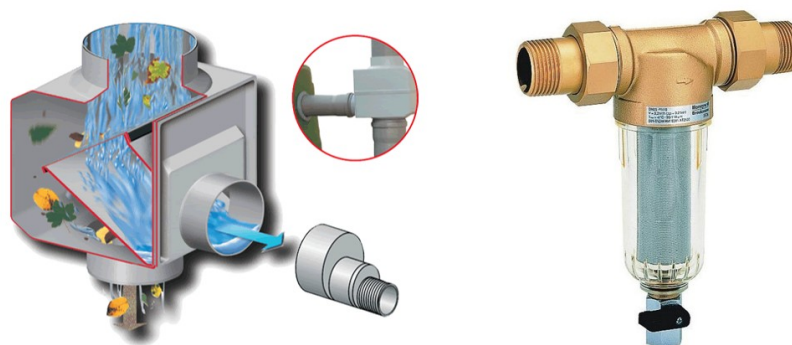


Fig. 4. – Second level filters

Multistage main line purifiers are third level filters. Today there are many varieties with different flow rates (10-60 l/min). They trap particles insoluble in water in the range of 1–20 μm (usually up to 5 μm) and are designed to filter up to 60 thousand liters of water with one cartridge (Fig. 5).



Fig. 5. – Multistage main line filter

Storage subsystem. For water storage systems, quite large tanks are made, which can be divided into two categories:

1. Ground, volume 750-2000 liters. (Fig. 6).
2. Underground, volume 2000–5000 liters. (Fig. 7).

The material most commonly used to make the tank is polyethylene. You can also find tanks made of concrete, fiberglass or steel. Synthetic rainwater storage containers have similar characteristics as their analogs made from other materials, at the same time they are much lighter, and therefore more convenient for transportation and installation.



Fig. 6. – Water storage tank (ground)



Fig. 7. – Water storage tank (underground)

Pumping subsystem. The pump is an indispensable part of the system if the tank is underground. Without a compressor, ground tanks can be used for drip irrigation of an area (with a recommended installation height of at least half a meter), but for most other needs the compressor is necessary. There are many types of compressors for pumping water in a pipeline, some of them are shown in Fig. 8. The most convenient in service are surface and portable pumps.



Fig. 8. – Types of compressor systems

Control subsystem. Today it is difficult to imagine any engineering system without automation. To control the system for collecting, storing and using rainwater, the following are used: solenoid valves, water level sensors in the tank, a relay to turn off the power of an electric pump and a main controller. The block diagram of the subsystems interaction is shown in Fig. 9.

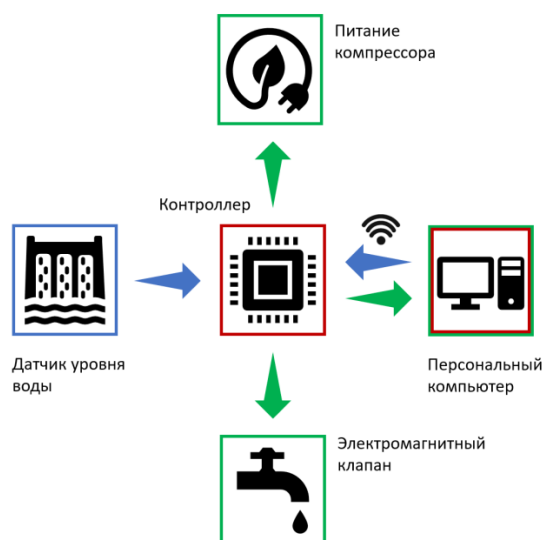


Fig.9. - Block diagram of the subsystems interaction

The controller controls the electronics: it processes the sensor readings using predefined programmes, and issues control commands for other electronic components of the system. The most popular controllers, which have gained wide practical popularity for solving similar problems, are Arduino single-board small-sized computers (Fig. 10).



Fig. 10. - Arduino small-sized computer

There are different types of water level sensors, namely: float; capacitive; radar type; hydrostatic; ultrasonic. They can act both as a signaling device (giving impulses when the limit

is reached) and as a water level gauge (providing information on the amount of liquid in the tank at any time). Any of these is suitable for implementation into the control system, however, the signaling device (discrete sensor) is a more budgetary option than the water level gauge (analog sensor). The float sensor and water level gauge are shown in Fig. 11.



Fig. 11. – Float sensor and water level gauge

Solenoid valves are used in the pipeline to regulate water flows (full or partial transition from “fully closed” to “fully open” position). In case of emptying the tank, the transition to the pipeline water supply is carried out. If the tank is full, the transition to rainwater supply is carried out. The critical value at which changes occur is determined by a water level sensor (water level gauge or alarm device). The solenoid valve is shown in Fig. 12. The switching circuit is shown in Fig. 13.



Fig.12. – Solenoid valve

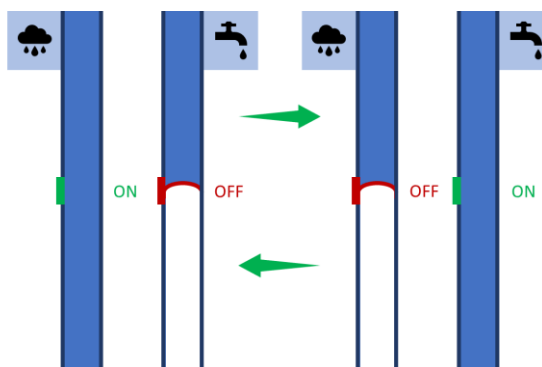


Fig.13. – Switching circuit

The pump power relay is necessary to timely turn off and on the pumping of rainwater (simultaneously with switching the valves). Modern pumps are controlled by a pressure switch, but this will not be enough for the system under development. The operation principle of the power relay is shown in Fig. 14.

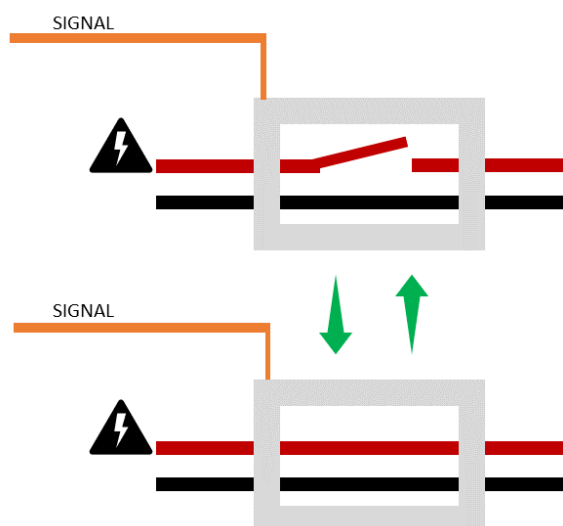


Fig. 14. – Operation principles of the power relay

To test the proposed system for collecting, storing and using rainwater, a country house with an area of 100 m², located in the Penza region (Bessonovka village), was chosen. The average rainfall in spring, autumn and summer is about 400 mm per year. Taking into account the drainage coefficient of the sloped roof ($C = 0.75$), up to 30 thousand liters of rainwater are expected at the output of the collection subsystem. The best option would be to use the total capacity of two ground tanks of 1000 liters each. The site diagram is shown in Fig. 15.

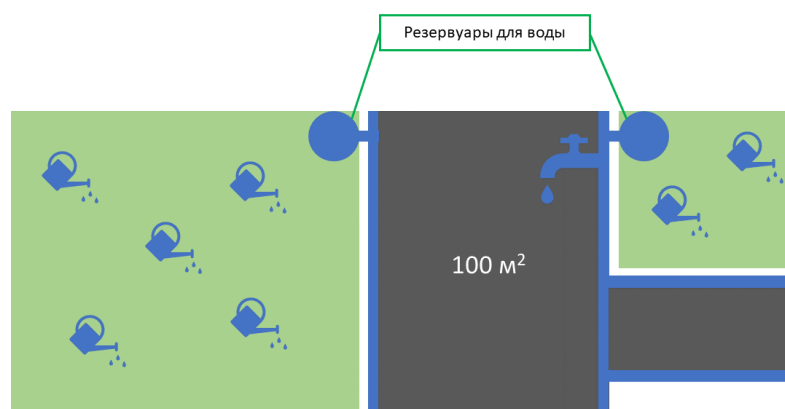


Fig.15 – Site diagram

The project economic justification:

To implement a prototype of the system, it will be necessary to purchase the following components:

Table 1 – Cost of materials and equipment

No.	Title	Total number, pcs.	Cost, thousand roubles
1.	Galvanized gutter, 2 m	10	3,1
2.	Galvanized gutter connectors	8	0,8
3.	Galvanized gutter plugs	4	0,2
4.	Galvanized gutter holder	8	0,8
5.	Galvanized pipe, 2 m	6	1,9
6.	Galvanized leader head	2	0,5
7.	Water gutter mesh, 2 m	10	2,1
8.	Filter for rainwater pipe	2	5,9

9.	Water tank, 1000 l.	2	22,8
10.	Centrifugal pump (surface), 1100 W, 5400 litres per hour	1	11,8
11.	Portable pump (for watering from the tank), 400 W, 3780 litres per hour	1	10,3
12.	Hose for the pump, 10 m, with a filter	1	2,0
13.	Rainmaster Trio main filter	1	7,6
14.	Arduino single-board small-sized computers (Wemos Mini)	2	0,7
15.	Float switch	2	2,2
16.	Solenoid valve	2	4,1
TOTAL			76,0

Expected project outcomes:

As a result of the project implementation, the efficiency of rainwater use in a country house will increase by using rainwater to irrigate the site; by using rainwater in the house for domestic needs; by using a tank to stabilize water supply throughout the day; by protecting basements and foundations of buildings from excess moisture; by reducing fresh water consumption and slowing down the development of environmental problems; by partially reducing costs for water supply.

The project can be successfully scaled up to similar country houses.

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