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A Study of the Water Quality of Rooftop Rainwater Collecting Systems

Namrata Arya
Sanskriti University, Mathura,
Uttar Pradesh, India
Email Id- namrata.sobas@sanskriti.edu.in

Krishna Raj Singh
Sanskriti University, Mathura,
Uttar Pradesh, India

ABSTRACT
Rooftop rainwater collecting as an alternative supply of drinking water is gaining popularity, particularly in poor nations. The existing data on the water quality of rooftop rainwater collecting systems are reviewed in this article. The impact of several variables on the physicochemical and microbiological quality of collected water is addressed. Different contaminants in roof runoff, such as heavy metals and trace organic pollutants, are compared from different regions of the globe. The findings indicate that the quality of water collected from roof catchments often falls short of drinking-water standards. Unless specific precautions are followed during rainwater collection and storage, most studies show that collected water is highly polluted microbiologically by a range of indicator and pathogenic organisms. In certain instances, heavy metals and trace organics may cause difficulties. The study concludes that the cleanliness of rainwater collected from roofs should not be taken for granted, and that the water should be analyzed for microbial contamination in particular. To make the gathered rainwater drinkable, it would need to be treated properly. The study also highlights the need for further research into appropriate design and management methods for roof-collected rainwater sources to avoid contamination.

Keywords
Rainwater Harvesting, Rainwater Quality, Roof Catchments, Roof Runoff, Water Quality.

1. INTRODUCTION
A significant part of the world's population lacks access to clean drinking water sources. According to WHO/UNICEF, a billion people lack access to “improved drinking-water sources Despite significant attempts to provide clean, piped communal water to the whole world's population, the truth remains that safe water sources will not be accessible to everyone in the near future[1]. The World Health Organization's Millennium Declaration set a target of reducing the percentage of the world's population without access to clean water by 2015. It is obvious that all-feasible measures must be explored to alleviate the drinking water issue, maximizing family control over their own water security. In this context, rainwater collecting is gaining popularity as a source of drinking water throughout the globe. While rainwater may be collected and stored in a variety of ways, this article concentrates only on rainwater collection and storage from individual home roof catchments. Rainwater harvesting was formerly the primary choice for individuals living in water-scarce locations in rural parts of poor nations, where they had to manage their drinking and domestic water requirements[2]. Rainwater collection has grown increasingly important in recent years, especially in regions with abundant rainfall, due to widespread pollution of surface and groundwater resources by microbial and chemical pollutants.
Governments all around the globe are increasingly enacting laws to encourage greater use of rainwater[3]. Several state governments in India, for example, have passed laws requiring rooftop rainwater collecting systems to be installed in newly built buildings in metropolitan areas. Subsidies are also being offered by governments to encourage the adoption of rainwater collection devices. Even in developed countries like Germany, Denmark, Australia, and New Zealand, pipe-bound rainwater utilization in private households, public buildings, and industry is being implemented with the goal of conserving valuable drinking water by replacing it with collected roof runoff rather than flushing toilets. While rooftop rainwater collecting is popular, the quality of collected rainwater has received little attention until recently[4]. The quality of collected rainwater is very important in poor nations where it is utilized as a source of drinking water. Several studies from across the globe have recently attempted to assess the quality of roof runoff. The majority of these research, on the other hand, are from industrialized nations' metropolitan regions, with the goal of establishing the impact of roof runoff in urban storm water pollution rather than the use of collected roof runoff. The quality of water collected from roof catchments is the subject of this article[5]. Fig. 1, illustrates the rain water harvesting cycle used by different households.

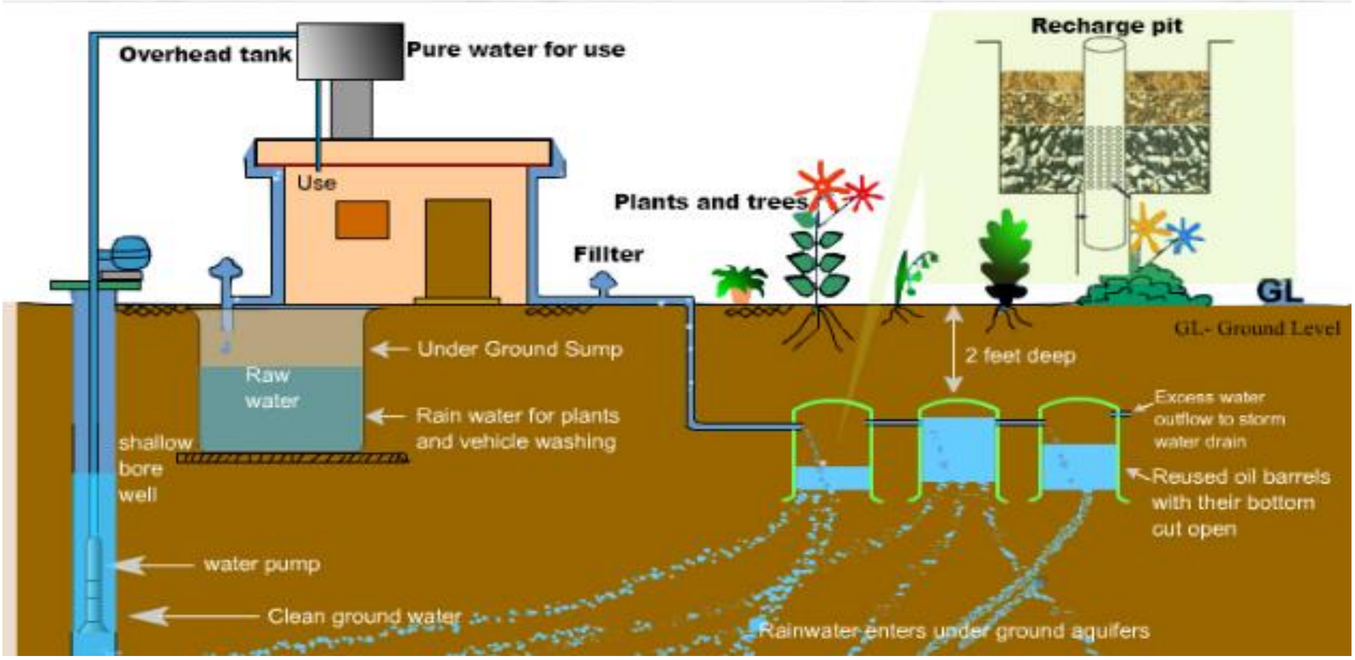

Figure 1: Illustrates the rain water harvesting cycle used by different households[6]

The effects of heavy metals and trace organic pollutants in roof runoff, as well as other variables that influence physico-chemical and microbiological water quality indices, have been addressed. The study also looks at the alterations that may occur after rainwater has been collected and stored in the harvesting devices[7]. It rains down on the roof, gathers debris, dissolves heavy metals on metal surfaces, and finally flows into storage. Depending on the substance utilized, changes may occur during storage. Many studies have looked at the microbial quality of roof-collected rainwater. Some of the most current research on rainwater collecting systems have come from all around the globe. For these tests, water samples were taken straight from the roof or from storage systems. Because of the differences in design, sampling, and analytical methods, direct comparison across these research is challenging. Several variables influence the microbiological quality of rainwater collected[8]. Roof contamination and the quality of roof materials are two examples. Rainwater from metallic roofs has a higher bacteriological purity than rainwater from other kinds of roofs.

Many species will be killed by the dry heat generated by a metal roof in direct sunshine, particularly in tropical regions. The microbiological quality is also influenced by the features of a rainstorm event. As a consequence of increasing levels of deposition on rooftops, pollution of rainwater increased with longer dry intervals between rainfall episodes. They also discovered that rainfall intensity had an impact on runoff quality[9]. The impact of storage duration on the microbiological quality of rainwater has been studied. While some research

indicated that the quantity of bacteria decreased with storage, others discovered that the number of bacteria grew. Long-term storage of rainwater did not result in a reduction in the numbers of some bacterial strains, according to a research. Faecal coliforms, total coliforms, and faecal streptococci, on the other hand, quickly decrease in rainwater storage tanks. The availability of nutrients and the appropriateness of - environmental conditions for development in rainwater storage tanks are likely to be the cause of these observed discrepancies. According to the results of a study of over 100 rainwater tanks used by indigenous people in rural Australia, the tank size was the most important factor affecting microbiological quality, with smaller tanks exhibiting greater levels of bacterial contamination. Because none of the tanks had any mechanical measures to preserve the water quality, tanks with smaller capacity acquired a higher proportion of contaminating microorganisms for the same catchment area. Furthermore, sludge deposited at the bottom of the tank was more likely to get agitated and mixed with standing water in smaller tanks. As a consequence of this research, it seems that just installing certain first-flush devices would result in a significant improvement in microbiological water quality[10].

Traditional markers for evaluating the microbiological quality of rainfall include total coliforms and faecal coliforms. Aside from these species, other investigations discovered the presence of harmful and opportunistic organisms in collected rainwater. Bacterial pathogens including Salmonella, Vibrio, Aeromonads, and Legionella, as well as protozoan pathogens like Giardia and Cryptosporidium, are commonly found in roof-collected rainwater. Rainwater is no exception to the numerous myths that exist in the globe. Rainwater is often associated with sewerage, pollution, and even baldness. Do you believe these concepts are correct? Despite the fact that such worries may originate from a widespread misconception, we seem to embrace them as scientific truth. The truth will be revealed in this chapter: rainwater is very clean and harmless. Let's take a look back at a time when pollution was not such a major issue. We don't even have to go back that far. Consider the 1960s and 1970s. Children from the neighborhood were running around in the streets, unconcerned about obtaining water.

2. DISCUSSION ON WATER QUALITY OF RAIN WATER

There was never a scarcity of water since mountain valleys, wells, and pumps were all readily available. Besides, they could just gaze up at the sky, open their mouths, and collect the rainfall whenever it rained! But what do today's youngsters do when it rains? They dash inside, recalling their parents' cautionary words, "Don't stay out in the rain!" Rainwater is polluted, and it may cause you to become bald!" Why don't we think of anything else? Consider a park picnic with your family. People eating their lunch on the lawn with their bottles of water ("bottled water"). People believe that bottled water is the safest type of drinking water since it goes through a "purification procedure." What if I ask them to drink rainwater instead? While they may think it's a weird concept, there is proof that the bottled water they're drinking began out as rainfall. Yes. Rainwater is used to make bottled water, which we regard to be the purest type of water. In reality, rainfall is the source of all water, including water from taps, valleys, and rivers.

Let's take a look at the source of the problem, using tap water as an example: The river or the lake - Tap water - Water pipe - Filtration plant - Water intake system - Rainwater - Water from the valley as you can see, the process comes to a close with rainfall. When it comes to water circulation in the natural world, rainfall is at the very top of the cycle. As a result, we may drink rainwater that has not been treated. This is because rainfall is nothing more than clean, distilled water evaporated from the sun. When rainfall falls from the sky, however, substances from the air and ground dissolve in it. Fortunately, rainfall becomes mineral water as it soaks into the earth. This water (groundwater) is generally considered safe to drink. Rainwater that falls to the ground, on the other hand, does not just soak into the soil; it travels all over the place. It becomes wastewater if it falls on rubbish because it is polluted. It may also flow into river systems and into the sea. More contaminants are added to rainfall as it disperses, and the water becomes less useful. Then we pay a hefty amount to cleanse it. This is the straightforward truth. The solution to this issue seems to be self-evident. Rainwater that has not yet reached the ground is the purest. Rainwater is inherently beneficial, therefore we must devise a method of collecting it before it becomes polluted. However, we find it difficult to fathom washing our faces or bathing with rainwater, much alone drinking it. However, we must save water since water scarcity is a major issue. Rainwater may avert floods and droughts in addition to alleviating water shortages. It can also help to clean up rivers and avoid contamination of groundwater. Furthermore, we can decrease the urban heat island effect, resulting in a more comfortable urban environment. Water, on the other hand, is a whole other issue.

To begin with, all living creatures need water to survive. 70% of our bodies are made up of water. Without 5% of our body weight in water, we become unconscious, and without 12% of our body weight in water, we die. So, although we can last 4-5 weeks without food, we can only go one week without water. Without water, our everyday lives come to a halt. We can't cook, dispose of waste, do washing, or clean a home if we don't have access to water. Farmers are unable to work on their farms. Conflicts over water erupt amongst African tribes suffering from a water scarcity, injuring a large number of people. So, how much do we know about water, which is an unavoidable part of our daily lives? To put it another way, what is our country's adult "water ignorance rate"? I'll provide a few instances. As previously stated, we utilize rainwater that has been cleansed after falling on the ground and becoming contaminated. This is believed to have stemmed from apprehension about the safety of rainfall, but when we look at the opposite side, there is a logic of interest among water-related organizations. Another thing to consider is our country's water use. We frequently remark that we squander as much water as we consume. That isn't entirely correct. According to the government study, Koreans consume more water than people in other nations. Is this, however, correct? Was the report's statistics compared to the quantity of water used in other nations correctly? It's difficult to find individuals who are as frugal as Korean housewives. Let's look at it from a more scientific standpoint by estimating how much water we consume on a daily basis.

In water bills, for example, we can see that the water rate and use are denoted by the “m3” unit. We can calculate how much water a person consumes each day by multiplying it by 30 days and the number of family members. When we dig further, we find that this number is lower than what the government claims. We can see what the issue is by looking at this basic diagram. Koreans, by the way, have a misunderstanding about something. It has to do with acid rain. Rain promotes baldness, which is a widely recognized and acknowledged truth among humans. You may have heard that acid rain causes sculptures to deteriorate. In primary school textbooks, the tale of acid rain is told. Of course, the phrase "acid rain is terrible" is written in a negative tone. However, there are a lot of misconceptions and prejudices here. First, let's speak about the ending. Although rain includes acidity, the amount of acidity is not detrimental to human bodies. The next chapter will go over the history of acid rain. Adult ignorance of water is very high, which is difficult to quantify in numerical terms. Water management has only been handled by professionals in few nations, therefore the issue of lack of information about water is not unique to our country. However, in recent years, comprehensive water management has been proposed as a solution to this problem. The goal of this movement is to inform and educate local people as well as specialists about the water problem. This is unmistakably a paradigm shift. The second World Water Forum was convened in The Hague in 2000, and this story was addressed there. The conclusion is that water should be everyone's concern. This is the worldwide commitment to eradicate "water ignorance." I hope our nation keeps its commitment.

In summary, we need to comprehend water from the perspectives of environmental, development, industrial, and education policies, and we need to encourage local people to participate. You are now a water agent. Traditional indicators have been questioned as to their appropriateness for evaluating the potential health hazards connected with the intake of collected rainwater that may be infected with a range of opportunistic and pathogenic bacteria. A recent research from New Zealand's rural regions found a link between the prevalence of Aeromonas and different indicator organisms in roof-collected rainwater. Aeromonas spp. were more likely to be found in the water supply of households reporting at least one person with gastrointestinal symptoms in the month previous to sampling than those without symptoms. In order to determine the appropriateness of the Aeromonas group as a microbiological quality and health risk indicator in roofcollected rainwater sources, further study is needed. Virus levels in rainwater must also be monitored, which necessitates more research.

While the microbial quality of rainwater is often questioned, it should be noted that in many cases, collected rainwater is still the greatest choice in terms of microbiological quality. Traditional rainjar water was shown to be better in terms of microbiological purity in a research performed in Thailand. Other studies have shown that the microbiological quality of stored rainwater is frequently superior to that of other drinking water sources such as shallow groundwater. In many cases, appropriate actions may still enhance the quality of collected rainwater. Many research on the physico-chemical properties of roof-collected rainwater have been published in the literature, and these studies from all over the globe show that, in general, the physico-chemical quality satisfies the drinking-water quality standards, with one noteworthy exception. The concentrations of key ions such as calcium, magnesium, sodium, potassium, chlorides, sulfates, and nitrates, on the other hand, vary greatly. Variation reflects variations in roofing material and treatment, roof orientation and slope, regional air quality, and precipitation parameters. With the passage of time and the age of the tank, the pH value decreases. pH variations between different roofing materials were discovered via chemical analysis. The breakdown of roof material, not the deposited aerosols, was blamed for a change in alkaline values for fibrous cement. The previous conclusion was debunked. They discovered that the breakdown of the roof covering material was minimal. Chemical purity varies significantly depending on roof material and roof, gutter, and storage arrangement.

Roof runoff has a pH that is within permissible standards. The pH of runoff from a wood shingle roof was lower than rainfall. Wood shingle roughness and cracks trap water, allowing wood decaying organisms to penetrate deeper into wood, plants to develop, and organic matter to decay, and as a result, more H ions are produced due to weathering and organic matter decomposition. As a result, wood shingle care and upkeep are critical in terms of roof runoff quality. All samples included cations such as sodium, potassium, and calcium, as well as anions such as chlorides, sulfates, and nitrates, with sodium and calcium having the greatest concentrations among the cations. Potassium and sodium showed the highest rise in macro ion concentration upon passing over the roof surface. The variations across roofs clearly showed that the ions came from the roof material; fibrous cement, which had more calcium, and concrete tiles, which had more potassium and calcium, were more sensitive to weathering, while dry deposition had a small role. Acidic ions like as sulfates and nitrates, on the other hand, had a different roof contribution and were transferred via deposition. The weathering of a gravel roof generated calcium and alkalinity, while the tile roof provided a minor supply of suspended particles and alkalinity. A zinc roof's high particle load was ascribed to the metal's severe weathering combined with a flat surface that is susceptible to particle wash off. Roof runoff from four different materials (zinc, slate, interlocking tiles, and flat roofs) was analyzed and found to be fairly comparable.

Another research was carried out to investigate the impact of location as well as the seasonal behavior of contaminants in runoff. Concentration differences. The effect of prior dry time, precipitation intensity, and material roughness on the concentration profile of suspended particles and inorganic ions was also investigated. When rain intensities were low and surfaces were rough, a change was observed in the typical run-off profile, which began with a high pollution load and exhibited a declining tendency. Within the course of an event, the suspended solid concentration of tar felt increased. There is a strong linear connection between suspended solid concentration in roof runoff and the following rain event characteristics: dry weather length, rain intensity, and rain duration. Because of their toxicity, pervasiveness, and inability to be chemically converted or eliminated by simple treatment methods, heavy metals are of special importance in rainwater collecting. While rooftops are excellent collectors of particle fallout from the environment, leaching and degradation of roofing materials may result in heavy metal contamination.

A variety of researchers have discovered different amounts of heavy metals in roof runoff. This table summarizes the heavy metal concentrations in roof runoff reported in recent studies. The relative contributions of atmospheric deposition and roofing materials to heavy metal pollution from roofs have been attempted. Although copper concentrations often exceeded freshwater quality requirements, differences in copper concentration between roof runoff and rainfall, as well as between runoff from any of the four roof types examined, were determined to be statistically insignificant. This indicates that the copper content of the roofing materials was insignificant. This was not the case for other metals, since the zinc content in rainwater rose when it came into contact with the four different kinds of roofs. There has been several research on the partitioning of metals in roof runoff, which has an impact on its toxicity. The partitioning of metals into particulate and dissolved phases was discovered to be dependent on the kind of roofing and runoff depth. The aforementioned ratio did not vary with runoff depth for a polyester roof, but it did for a tile roof. All heavy metals were present in dissolved form on a gravel roof. Acid rain is linked to high metal levels in rainfall, and a low pH has been linked to higher lead levels.

3. CONCLUSION AND IMPLICATION

Water quality in rooftop rainwater collecting systems is becoming more of a concern, especially in poor nations where the collected water is utilized for drinking. According to studies conducted in many areas of the globe, water quality is often questionable, particularly in terms of microbiological purity. Physicochemical quality of collected rainwater seems to be determined by roof material, rainfall intensity, dry time before a rainfall event, and proximity to pollution sources, among other variables that influence the water quality of roof runoff. In terms of microbiological quality, the roof material and any dry periods may have a major impact. However, a few studies indicate that well-maintained rainwater is a high quality supply, typically falling into the WHO "low risk" category. Poor collection and maintenance methods will significantly decrease the quality. This emphasizes the need of appropriate construction and management methods to keep potable roof-collected rainwater sources safe. All studies indicate that rainwater must be treated before it may be utilized as a source of drinking water.

More research is required to determine the microbiological danger of drinking water from home rainwater collecting devices. According to a few studies published in the literature, drinking untreated rainwater poses a significant health risk to consumers. Bacterial diarrhea, bacterial pneumonia, botulism, protozoal diarrhea, and diarrheas caused by Giardia and Cryptosporidium have all been linked to the intake of untreated rainwater. The majority of research on this topic come from

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industrialized nations. In developing nations, where the use of rainwater as a source of drinking water is becoming increasingly common, it is necessary to evaluate the health consequences of rooftop rainwater collecting systems. There is also a need to create some cheap and quick field-testing techniques that may be used in poor nations to detect microbial contamination in drinking water. In this respect, theH2S strip test based on H2S generation by sulfate-reducing bacteria seems to be promising.

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