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Condensed Water Recycling in an Air Conditioning Unit

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Abstract:
Background: *Water resources are conserved by the treatment of waste water or the recycling of water for use in many beneficial uses such as drinking, irrigation, toilet flushing, and industrial activities. It also provides financial benefits. The primary goal of installing an air conditioner is to obtain a cooling effect. Water is produced as a by-product of air conditioners at no cost and is usually wasted in Bangladesh. The goal of this thesis is to determine the most important properties of condensed water from an air conditioning unit. This research also shows how this unused valuable water can be put to good use.*
Materials and Methods: *Total hardness, turbidity, dissolved solids, alkalinity, electrical conductivity, copper, lead, iron, manganese, and chloride content, dissolved oxygen, pH, chemical oxygen demand, total suspended solids, biological oxygen demand, and corrosivity are some of the chemical tests that are used in water analysis. In the meantime, sample quantity measurements were carried out.*
Results: *The pH of the obtained water is quite basic, near to neutral. The concentrations of total dissolved solids, copper, lead, total hardness, electrical conductivity, and alkalinity in condensed water are all within very narrow limits. Every 2-ton air conditioner produced 25 liters of water each day on average. This study demonstrates the viability of using condensed water in the battery, automotive radiator, boiler, toilet flushing, and laundry.*
Conclusion: *Condensed water can be used in a variety of applications, including vehicle batteries, radiator water, toilet flushing, industrial reasons, washing clothes, aquarium fish culture, and irrigation. With regular treatment and disinfection, this condensed water can also be utilized as drinking water. The problem of water shortages can be mitigated by recycling water from many industries, such as waste air conditioning water.*
Key Word: *Recycling; Condense water; Air conditioning unit; Properties of water.*

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I. Introduction

Water is a life-sustaining necessity for consumption, domestic, engineering, and agricultural purposes. Its supremacy, as well as the amount that varies across the planet and throughout time, are important components in every zone's necessary growth. Any change in the typical superiority of water could disrupt the stability scheme as well as make nominated consumptions harmful [1]. It is estimated that 70% of all water is used for agricultural purposes, with 15-35 percent of irrigation withdrawals being unsustainable [2]. It takes around 2,000-3,000 liters of water to provide enough nourishment to meet one person's daily nutritional needs [3]. It is estimated that 8% of all water used in the world is used for domestic purposes. Agriculture irrigation, livestock drinking, household use, and industrial uses of water are all detailed in depth. [4]. Industry consumes 22% of the water on the planet [5]. The oceans contain 97.6 percent of all available water on the planet. The remaining 2.4 percent is made up of freshwater. Only 0.31 percent of this 2.4 percent is not concentrated in the form of ice on the Poles. Less than 0.02 percent of the water on the Earth's surface is available in rivers and lakes as potable water [6]. The topic of water reuse has sparked plenty of investigations and research, primarily in places where water is scarce. Water reclamation is most commonly done in industry and agricultural [7]. In Mediterranean and Middle Eastern countries, projects aimed at effective water management, treatment, and reuse have been implemented, with the goal of increasing water supply security by raising public awareness and adopting innovative solutions to each scenario [8]. Water reuse management, scale, water quality, and safety criteria need to be investigated and improved. In countries like China, where multiple treatment stations are operational and show rising results in terms of water reuse % to increase environmental sustainability [9], water reuse has been done on a wide scale. Studies proposing ways for establishing water reuse systems have been created in places with a good history of precipitation, and some of them have corroborated the efficiency by lowering water consumption by 35 percent, such as in schools in Taipei's district [10]. Various numerical models have been developed to reuse the waste water by enhancing the heat transfer rate through the turbulent water [11] [12]. This water is of reasonable quality, and after a few treatment stages, it could be used as both drinking and non-drinking water, serving a variety of needs in building operations [13] and fabricating natural fiber composite materials [14]. A 2-ton air conditioner wastes 3.5 to 4.5 liters of water each hour [15]. In Bangladesh, the average manufacturing water usage is reported to be between 250 and 300 gallons per kilogram of cloth produced [16]. This is the same amount of water used on a daily basis by two persons in Dhaka. The world standard for fabric manufacture is 100 liters of water per kilogram [17]. The main goal of this research is to determine the qualities of condensed water and to assess its suitability for various applications such as battery water, water used in boilers, industrial purposes, irrigation, washing cloth, fish culture in aquariums, and drinking water.

II. Methodology

Collection of Condensed Water

Modern air conditioning systems do not draw air into the chamber from the outside; instead, they recirculate progressively cold air into the space. Because this intimate air is constantly humidified, the refrigerating portion of the method causes atmospheric hot water vapor to condense on the refrigeration loops and drop from them downcast on top of a fastening plate at the bottommost of the part, from which it must then be transmitted exteriorly, typically through a gutter hole.

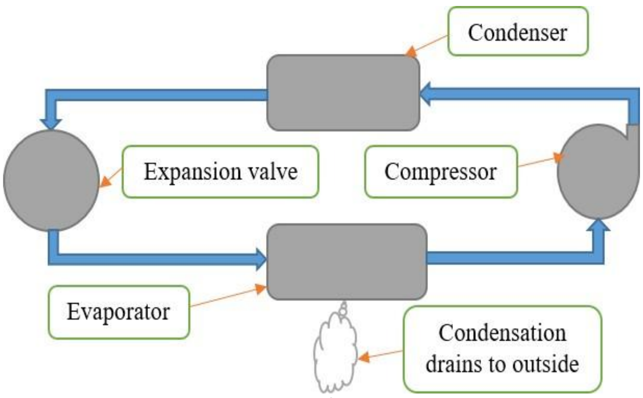

Figure 1: *Formation process of water in air conditioning unit*

Temperature affects the amount of water vapor stored in the air. At a higher temperature, more water vapor may be stored. As the temperature drops, the amount of water vapor that can be held in the air decreases. Water vapor will begin to form water droplets on surfaces that are cooler than dew point. Temperature affects the amount of water vapor stored in the air. At a higher temperature, more water vapor may be stored. As the temperature drops, the amount of water vapor that can be held in the air decreases. Water vapor will begin to form water droplets on surfaces that are cooler than dew point. Figure 1 depicts the production of water in an air conditioning machine.

Because the evaporator coils are at a very low temperature, usually around 4–5^{o} C [18], the water is created in the internal unit. When air is forced on evaporator coils, the temperature of the coil surfaces is significantly lower than dew point, and the air cools down, causing water to condense on the coils. The water is then drained out through the drain pipe, which is a split AC, and the power wires and copper tubing are dusted out.

By way of this dampness has not at all disbanded mineral deposits in it, it not ever reasons inorganic accumulation on the loops, although if the element is set at its toughest refrigeration situation as well as occurs to consume insufficient rotation of air from side to side the loops and similarly understandings a disappointment of the thermistor which intelligences the atmospheric temperature in the chamber, the loop's flippers can progress a coating of frost which will then raise in addition to finally chunk the rotation of air on the cold adjacent of the component overall in a constructive response coil that will reason the creation of a frost chunk intimate the unit. Only insignificant amounts of cold air will continue to emerge from the exhaust opening until the ice is no longer involved, at which point it will be OK to dissolve. If the air moisture level is low, this will happen right away. Once ice starts the process on the evaporative flippers, it will reduce transmission effectiveness and cause the creation of more ice.

Figure 2: Sample water collection

Table 1: Conditions and collections of condensed water both practically and theoretically

Initial Conditions (Before 20 minutes)			Final Conditions (After 20 minutes)			Condensed Water (Practical)	Condensed Water (Theoretical)
DBT (ºC)	WBT (ºC)	RH (%)	DBT (ºC)	WBT (ºC)	RH (%)	mL/20mi n	mL/20mi n
30	27.5	84	28.5	25.5	79	1050	1124
28.5	25.5	79	27.5	24	75	710	756
27.5	24	75	26.5	22.8	72	465	494
26.5	22.8	72	26	22	70	430	446
26	22	70	25	20.8	68	415	442
25	20.8	68	24	19.6	66	415	440

Experimental Data

Date: 17/06/2020 Unit Capacity: 2 TR Model no: GS-24V/I
Location: Heat Engine Lab, Rajshahi University of Engineering and Technology (RUET)

Typical Calculation for Condensed Water (Theoretically Calculated)

- Initial Condition: Dry bulb temperature (DBT) = 30^0 C Wet bulb temperature (WBT) = 27.5^0 C Relative humidity (RH) = 84%
- Final Condition: Dry bulb temperature (DBT) = 28.5^0 C Wet bulb temperature (WBT) = 25.5^0 C Relative humidity (RH) = 79%, Air Flow Rate, V= 1000 m^3/hr. By using this data, from Psychrometric Chart Specific volume of air, V_S = 0.89 m^3/kg dry air, Specific humidity in Initial Condition, W_1= 0.0225 kg/kg of dry air Specific humidity in Final Condition, W_2= 0.0195 kg/kg of dry air.
- Calculations

  Amount of Water Condensed
  = $(W_1 - W_2)\, m_a$ [Where, m_a is mass of air]
  = $(W_1 - W_2)\, V/V_s$
  = (0.0225-.0195) (16.67/0.89) kg/min
  = 0.0562 kg/min
  = 1.124 kg/20min = 1124 ml/20min = 3372 ml/hr.

III. Result

A. Comparison Diagrams:

As shown in Fig. 3., the theoretical value of condensed water is always greater than the practical value because of some water losses due to evaporation and a leakage problem. This graph also depicts the variation in condensed water quantity with relative humidity.

The average relative humidity of several months in Rajshahi, Bangladesh is depicted in Fig. 4. Because it is winter in Bangladesh from December to March, the relative humidity level is low. The remaining portion of the year, on the other hand, is monsoon and summer season, which is why the relative humidity level is high. The amount of condensed water obtained during the summer season is considerable due to the greater relative humidity. By combining Fig. 3 and Fig.4, the amount of condensed water produced in different seasons in Rajshahi, Bangladesh, may be simply calculated.

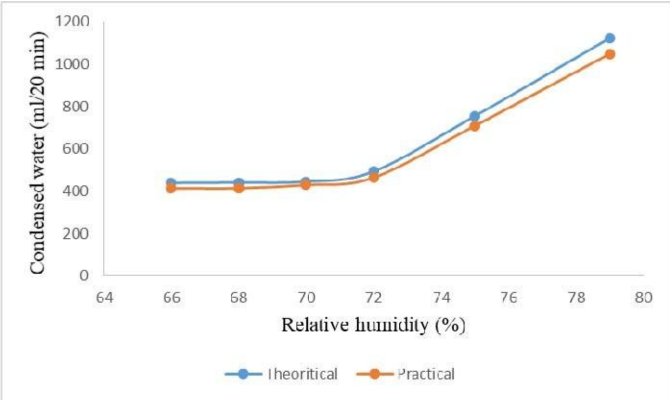

Figure 3: *Condensed water vs. relative humidity graph*

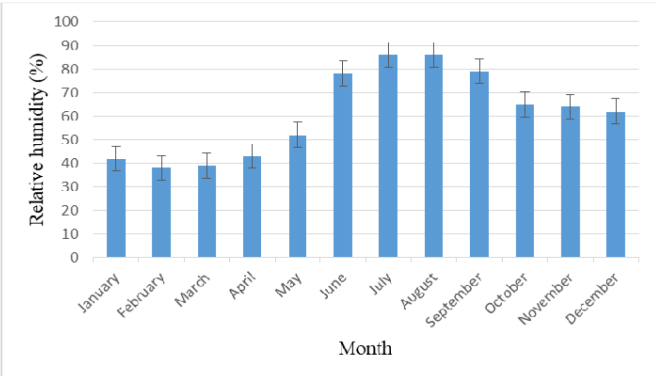

Figure 4: *Relative humidity of different months in Rajshahi, Bangladesh [19]*

Table 2: Shows tested properties of condensed water

Water Quality Parameters	Concentration	Bangladesh Standards [20]	Unit
Copper (Cu)	0.26	1	mg/L
Dissolved Oxygen	6.15	6	mg/L
Electric Conductivity	40	-	μS/cm
Lead (Pb)	0.002	0.05	mg/L
Nitrogen (Nitrate)	3.1	10	mg/L
pH	7.2	6.5-8.5	-
Total Dissolved Solids (TDS)	19	1000	mg/L
Total Suspended Solids (TSS)	1.0	10	mg/L
Hardness	40	200-500	mg/L
Turbidity	4.28	10	NTU
Iron (Fe)	0.09	0.3-1	mg/L
Manganese (Mn)	0.09	0.1	-
Chemical Oxygen Demand (COD)	6.23	4	mg/L

Biological Oxygen Demand (BOD)	22	0.2	mg/L
Alkalinity	27.6	-	mg/L
Chloride	0.6	150-600	mg/L
Corrosivity	40	-	µm/year

B. Properties of condensed water

Hardness, Chloride, Acidity, Chemical Oxygen Demand (COD), Alkalinity, Iron, Corrosivity, Turbidity, PH, and other parameters of the water were determined experimentally using the IS-3025 (Reffired-2003) technique. Table 2 compares the qualities of condensed water to the Bangladesh standard (Properties of water according to the Bangladesh Water Development Board), which is based on WHO (World Health Organization) guidelines.

C. Usage of condensed water

- Boiler purposes

The boiler's primary function is to generate steam by burning various types of fuel in its combustion chamber. As a result, water that is free of contaminants is necessary. Natural water sources, on the other hand, contain solid, liquid, and gaseous contaminants. Calcium and magnesium salts are highly detrimental in steam boiler water, and when polluted water is heated and steam is generated, they precipitate as solid residue and form a hard scale on the wall surface. The heat transfer method is hampered by the scale. Mineral acids in water are undesirable because they can produce a chemical reaction with boiler components, causing problems. As a result, it's critical to use water in the boiler that's free of these contaminants, and condensed recycled water is ideal for the job.

- Scale formation

Scale formation in the boiler drums of the feed water piping system and header tubes is caused by impurities in the water. This reduces the rate of heat transfer and causes tube overheating, which can lead to blistering and rupturing. Calcium and magnesium salts are primarily responsible for the formation of scale. After the scale has formed, the tubes should be cleansed using water or electrical power-driven revolving brushes and scissors that are struggling through the pipes during boiler repairs.

- Corrosion

Because of the acidity in the water, corrosion can occur in the boiler shell, tubes, and plates. The life of construction materials is shortened as a result of this. Corrosion is the damaging translation of metals bound to oxides or salts. The presence of oxygen, carbon dioxide, or chlorides dissolved in water causes corrosion. Small pits form as a result of oxygen-induced corrosion.

- Foaming and Priming

Soluble and insoluble salts, as well as organic contaminants in suspension, generate a layer of foam in the boiler drum. Foaming stops steam bubbles from rising to the surface of the water and escaping freely. Foaming can be caused by oil and other contaminants found in boiler water.

- Embrittlement

Caustic embrittlement is caused by caustic impurities, which are sodium hydroxide concentrations in water. The boiler metal becomes brittle as a result of this, and interior cracks emerge along seams below the water level. In this situation, the surface water requires thorough treatment to remove pollutants. The unclean water is chemically treated in various ways depending on the nature and concentration of pollutants, resulting in increased overall costs. However, water condensed from an air conditioner is free of contaminants such as aluminum sulfate, sodium sulfate, or ferrous sulfate, as well as oxygen, carbon dioxide, chlorides, and other mineral salts. As a result, this water can be utilized directly in a boiler to make steam, saving money.

- Radiator water

When extensive cooling is required, a radiator is used to cool an internal combustion engine. Water is used to cool radiators. As a result, water is unlikely to coagulate, and different sorts of additives, such as antifreezes, are occasionally employed to make it environmentally friendly. Because of the usage of surface water, which contains iron concentrations of 0.3-1 mg/L, as well as dissolved oxygen and other solid particles [21]. Those water components in an automotive radiator produce scrap and corrode, as shown in Fig. 5. As a result, the radiator's lifespan was considerably shortened. However, the iron concentration in air conditioning condensed water is 0.09 mg/L, and other solid particles are less than in surface water, according to a laboratory test result. As a result, rather than using surface water, this water is ideal for radiator use.

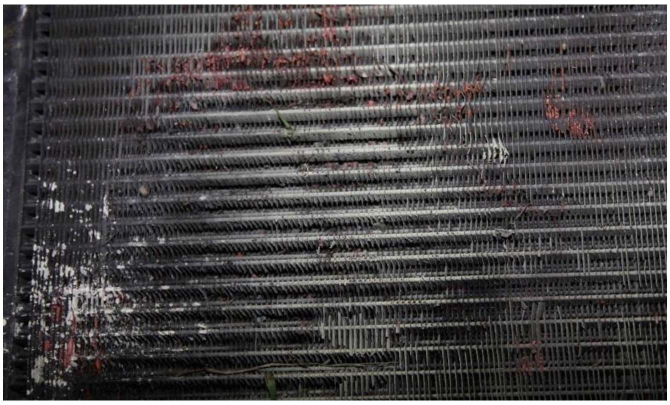

Figure 5: *Damaged radiator due to using surface water*

- Battery Water

The battery is made up of multiple plates that are enclosed in water and allow it to work. Throughout the operation, the chemical reaction fractured the water into hydrogen and oxygen gas. These gases evaporate from the battery, and the water level drops over time. The battery is made up of multiple plates that are enclosed in water and allow it to work. Throughout the operation, the chemical reaction fractured the water into hydrogen and oxygen gas. These gases evaporate from the battery, and the water level drops over time. It is critical to top up the batteries with pure water to keep it functioning properly. Mineral deposits and salts fill the holes and form a covering on the plates, disrupting the battery's typical electro-biochemical cycle that generates power. The presence of such organic ions might drastically reduce the battery's lifetime. Clarifying blow water just removes the postponed substance; it does not remove dispersed mineral deposits or non-ionic composites. There are no liquid mineral deposits, salts, biological or inorganic composites in distilled water that could harm the battery.

Table 3 shows a comparison of the parameters of battery water and condensed water. There are no liquid mineral deposits, salts, biological or inorganic composites in distilled water that could harm the battery. Table 3 shows a comparison of the parameters of battery water and condensed water.

The majority of condensed water's qualities are comparable to those of battery water. Only the electrical conductivity and total dissolved particles differ somewhat from battery water. The amount of total dissolved solids affects electrical conductivity. The number of dissolved solids can be minimized if sufficient purification is provided. The condensed water can then be used as a source of battery water.

Table 3: Shows Battery Water and Condensed Water Properties

Parameter	Battery Water Specification [22][23]	Condensed Water Specification
pH	6.5-7.5	7.2
Chloride	1 mg/L	0.6 mg/L
Lead	0.1 mg/L	0.002 mg/L
Hardness	Not detectable	40 mg/L
Iron and Manganese	0.1 mg/L	.09 mg/L
Electric Conductivity	5	40
Total Dissolved Solids	2 mg/L	19 mg/L
Corrosivity	0-47 µm/y	40 µm/y

IV. Discussion

Water is necessary for the survival of the entire globe. The world's technological growth is increasing the demand for water on a daily basis. At the same time, water sources are steadily diminishing. The goal of this project is to discover that an air conditioning unit is an important source of water and a viable industry.

The amount of condensed water produced by an air conditioning machine is often extremely tiny. However, in practice, a 2-ton air conditioning unit condensed an average of 3 liters/hour and the characteristics were practically distilled. This source of water has certain issues, such as how it varies depending on the season. This water is obtained as much as the calculated value throughout the summer season.

It is also affected by the air's relative humidity. When the humidity rises, so does the amount of condensed water, and vice versa. It loses a portion of the water due to leakage and evaporation. This loss can be reduced if a proper carrying and collection mechanism is in place.

To gather the water, no additional energy is necessary, and no further money is incurred. As a result, collecting and using water is economically viable.

V. Conclusion

The biochemical superiority of the experienced samples can comprehend that the water after a minor purification will have no adverse effect on the users' health, but abundant water for consumption without management is not recommended. As previously said, condensate water is suitable for a wide range of industrialized applications, and it is a free resource with no cost for management, no negative impacts on the environment, no harmful properties for instruments, and no health risks. This water can be used in a variety of applications, including vehicle batteries, radiator water, toilet flushing, industrial reasons, washing clothes, aquarium fish culture, and irrigation. With regular treatment and disinfection, this condensed water can also be utilized as drinking water. As a result, it demands a broad plan that includes organizing it into the water collection, storing it, and then using it as directed. The problem of water shortages can be mitigated by recycling water from many industries, such as waste air conditioning water.

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