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Assessment Lagging Performance Indicators of Cooling Tower Water Wastage at Refinery (Parco) & Possible Upgradations to Eco Design for Water Conservation

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Abstract

About 20% of energy in manufacturing is connected to refrigeration, heating water, the purpose of this research is to save environment by conserving water losses and these has to be replenished. Monitor rate of evaporation make up and blow down water superiority to authorize that the up-gradated structure is acting as predicted. Increasingly the most forward thinking using highly treated recycled water, side filtration, and option of ozone treatment, changing behavior of blow-down and replacing water saving equipment's or modifying to reduce energy in addition water needs, which save budgets in addition recover water management in the future. This will address the problems found through an environmental review of current and future cooling systems, the technological, economic and environmental implications, with possible technical and non-technical solutions. Considering the current water crisis around the world, it is essential to expand the functions of these wet refrigeration towers to decrease their water consumption with maintaining their performance, therefore it has a great potential to recycle water evaporation. Which has not considered so far? This retrofit research using possible up-gradations at different research study, Reference [22] at existing facility regarding environment improvements (sustainability & water conservation) to perform a realistic evaluation of this idea.

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Experimental data measured and dynamic Eco approaches performed to evaluate the water saving potential. The result shows that water losses at one unit control from maximum (440 m^3/hr) to minimum 108 $m^3/\ hr$ level to promote environment sustainability.

Keywords: cooling tower; make up water; evaporation rate; blow-down; water conservation; sustainability; Eco approaches.

1. Introduction

Water is one of the endeavor necessities for all industrial development systems including thermal power plant, Refineries, Fertilizers, cement, textile, Sugar, Leather and paper. The rare water is commonly drawn from intense water source such lake, canal, reservoir, and barrage. Treated manure water can be used as a foundation of rare water for the plants located adjacent to the cities. Hence, water is an essential input to a refinery. Water is a main input to many industries and it is imperative for human life. Pakistan is the country of most concern for water constraints, and the plants are located in water scarce or stressed areas. Water scarcity is already influencing industrial projects, causing delays and operational losses. Thus, there is aimed to minimize consumptive water requirement for refinery plants. Further, as water, resources become scarcer, human consumption like drinking and irrigation uses have high priority over industrial uses. Hence, it has been observed that water is becoming scarce, which needs to be properly utilized leaving no room for wastage, to ensure a sustainable development. At present, some of the projects those are already in pipeline are facing hurdles in execution and lacks viability due to unavailability of water allocation. Any level of initiative in the area of reduction in water consumption gains importance at this current scenario. So measures to be taken for reducing consumptive water than the designed value. This paper aims at discussing different aspect of water consumption in a refinery & device a simplified methodology to reduce the water. The strategy underline particularly on evaporative open mechanical induced draft cross flow cooling units, due to the spirit of evaporative cooling units, water mislaid from evaporation and blow-down has to be top off, in area where potable supply is abundant, cooling towers use potable water for making up the water losses in the cooling tower. However, as water supplies are increasingly unnatural, businesses and institutions can think about converting to recycled water to supply the make-up water. Evaporative cooling systems are compiled of two components: a heat exchanger and cooling units. The main function of cooling tower is to push out the heat from the heated water professionally. Heat is removed by transmitting it to air through evaporation. Public water systems use chlorine in the gaseous form, which is considered too dangerous and expensive for home. Private systems use liquid chlorine (sodium hypochlorite) or dry chlorine (calcium hypochlorite). To avoid hardness deposits on equipment, manufacturers recommend using soft, distilled or demineralized water when making up chlorine solutions. Injection is operated only water is being pumped. Trihalomethanes (THMS) disinfection by-product formed from degradation of plant material combine with free chlorine cause cancer chance element. Hence, cooling tower make up has enough. Potential for improvement and needs further study / optimization. When water has been fade away throughout cooling in the Cooling Tower, leaves behind resolved solids / salts in the system and increases total dissolved solid (TDS) level. This will increases the COC in the circulating water system. Cycle of Concentration refers to the ratio of impurities or the TDS in the make-up water. A particular Cycle of Concentration in a circulating water system is compulsory to stay away from any deposition in the condenser heat transfer tubes, which obstruct the plant efficiency. Hence, to maintain a desirable Cycle of Concentration, some amount of CW is to be removed on continuous basis from the system, called blow down. The amount of blow-down is calculated by the following formula [29].

Below down = Evaporation loss / (COC – 1)

The evaporation loss in Cooling Tower, generally for about 1.75 % of total Cooling Water flow, including drift loss and spillage etc, so there will be two types of loss in the Cooling Water system such as: [5]

1. Evaporation loss

2. Blow down low

Make up water is requisite to, meet those losses. Since the Cooling Tower has been working on evaporative principal, it is essential for Cooling Tower to know these evaporation losses. Improvements in water quality / water treatment technology, COC of Circulation Water system has been increased from 2 to maximum level 50. That leads huge decline in blow down water condition. Additionally, a technology to reduce the loss further below the designed value will be very essential considering significance of water. The amount of make-up is given by.

Quantity of Make-up water = Evaporation loss + Blow down

= Evaporation loss+ Evaporation loss (COC -1)

Cooling tower is a heat refusal mechanism that rejects waste heat to the atmosphere through the cooling of a water stream to a lower temperature. Cooling tower either use the evaporation of water to remove process heat and cool the working fluid to near the wet-bulb air temperature or, in the case of closed circuit dry cooling towers, rely solely on air to cool the working fluid to near the dry-bulb air temperature. In Cooling Water Return, the hot water flow is initiated descending throughout scatter needles into plug in the interior the tower. The dissimilar category of fills (splash, trickle, fills) that are presumed at creating extra exterior area to exploit contact among the Hot CWR & air, As air mount within the tower, it obtain the latent het of vaporization from the H2O & thus hot water is cooled [42].

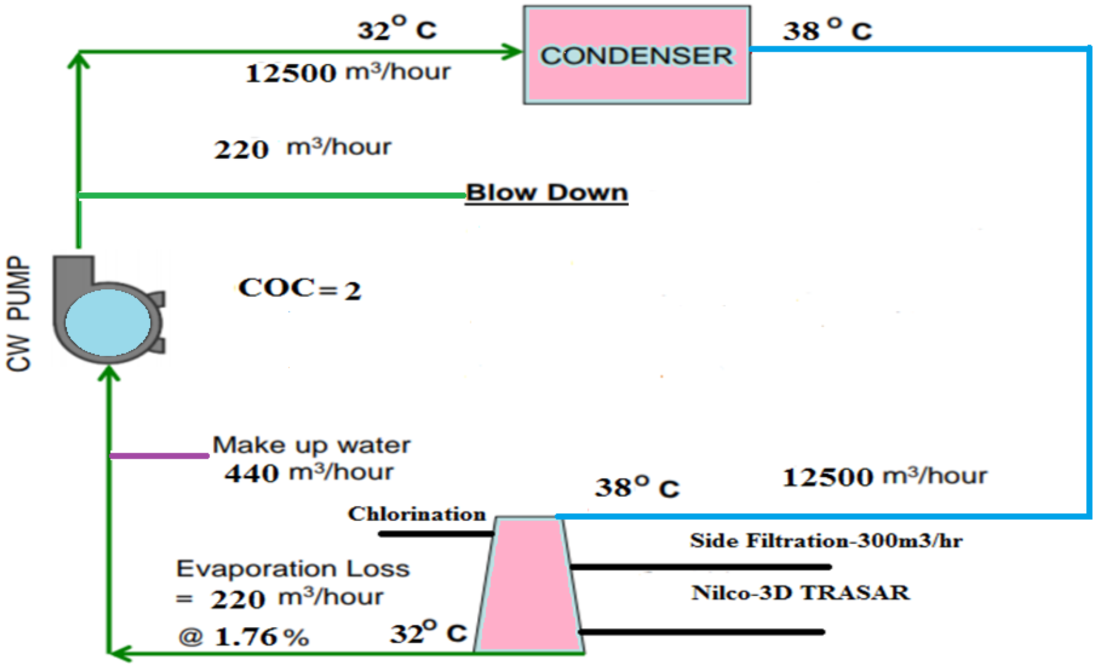

Figure 1: Presents system of blow-down and chlorination [28]

Water is essential to human life. Yet, worldwide, 2.1 billion people lack access to safe drinking water and 4.5 billion people lack safely managed sanitation services. Globally, eight forty four million people lack access to clean water. The consequences of unsafe water and poor sanitation are far-reaching, impacting health, education, economic productivity, and the dignity of those living in extreme poverty. In 1993, the United Nations established World Water Day to bring awareness to the importance and management of freshwater sources. Today, the UN Sustainable Development Goal #6 aims to bring an end to the crisis, with safe water and sanitation for all, by 2030.According to a report by the World Economic Forum, the world's water crisis ranks fifth on the list of issues threatening humanity's survival. A 2013 Global Water Institute report says over 700 million people across- 43 countries face water scarcity. Climate change, increasing water scarcity, population growth, demographic changes and urbanization already pose challenges for water supply systems. By 2025, half of the world's population will be living in water-stressed areas. Re-use of wastewater, to recover water, nutrients, or energy, is becoming an important strategy. Increasingly countries are using wastewater for irrigation — in developing countries; this represents 7% of irrigated land. While this practice if done inappropriately poses health risks. Every minute a newborn die from infection caused by lack of safe water and an unclean environment. However, investing in clean water saves lives, and according to the World Bank, promoting good hygiene is one of the most cost effective health interventions. (WATER-AID). “How can we make water available for all?” (WHO) half of the world’s hospital beds are occupied by patients suffering from diseases associated with lake of access to clean water (WHO). Demand is expected to outstrip supply by 40% in 2030, if current trends continue. Pakistan has already proven that decoupling water use from economic growth it possible. AS, in Australia, water consumption declined by 40% between 2001 and 2009 while the economy grew by more than 30% the most cost-effective way of decoupling water use from economic growth. It is estimated that about 768 million people around the world do not have access to good water [44]. Water, as the component of every cooling system. Cooling towers are an Waged component of many cooling systems that provide comfort or process cooling. Cooling tower systems operation is most efficient when their heat transfer surfaces are clean. However due to variations in the water source and their operating in an open environment, cooling towers are subject to four for water treatment comma comas, scaling, fouling and microbiological activity. These factors can significantly reduce the efficiency of the cooling towers.

1.1 Background

Researcher has stated research in that area of Pakistan which is situated between two Rivas (Indus, Chenab) where ground water level at 1980 were almost near 22 ft due to a lot of reasons (population, urbanization, industrialization absence). Now at the time of research 2020, these areas have been developed with having three big plants (TPS, AES LAL PIR, and KAPCO), One Oil Refinery (PARCO) and many sugars and tumbles industries, due to which the pound water level coalition is goes down 300 to 500 ft for agriculture as well as for drinking purposes. There is a serious concern for our next generations regarding water unavailability and sustainability of our ecosystem (Habitat destruction) e.g. skin, lungs diseases, deforestation & Birds migration, quality of water due to pollutions (water, air, land). The developments of these areas are good initiatives from Government due to rise of education level, infrastacture development, unemployment and media freedom, but there is a need of awareness (Enforcement of Law i.e. dispirit absence of water charges) for water conservation and Environment Sustainability. On behalf of this retrofit research at one-target industry, the scholar will prove the water savings and calculated overall approximate water wastage at main big industries (refinery) in Pakistan, eight refineries are in Operation (Pakistan Refinery Ltd, National Refinery Ltd, Pak-Arab Refinery Co, Attock Oil Refinery Ltd, Byco-1-11, and Enar-1-11). Proposed Refinery (Gawadar 3 Lac bpd, Hub Coastal 250,000 bpd, ORI 250,000 bpd, PSO Power China 3Lac bpd, Falcon Oil 40K bpd, Khyber Refinery Ltd Kohat 20K bpd) Expatriate Companies, British Petroleum 1954, ENI 1953, OMV 1956, MOL 1991, BHP 2001. National Companies, OGDCL 1961, PPL 1950, Mari Gas 1957, POL 1950 and OPI (Orient Petroleum industry) Services Company, Schlumberger 1926, Weather ford 1948, Halliburton l924, Baker Hughes 1987, Sprint and Eastern testing. Pak Arab Refinery (PARCO) is a cooperative enterprise founded in 1974 between the Government of Pakistan and the Abu Dhabi Emirate. The Pakistani Government holds 60% of the shares, although the Abu Dhabi Emirate holds 40%.

1.2 Objectives of Research

Following are the important points of study,

1. To highlight/chalk out the different basic causes for water losses at realm cooling tower and apply with alternate technical, non-technical past research solution.
2. To assess the most suitable up-gradated Eco approaches to reduce; influence of lagging key performance indicators.
3. To study the cooling tower water aspect on Environment (local and global).
4. To build-up Way Forward of Audit Control, Evaluation and management Operation.

2. Literature Review

Water and energy consumption in buildings has dramatically increased in current years with the growth of the metropolitan building industry. Water and energy conservation could be a vital step towards achieving environmental change in this field [2]. Because of the location of wet cooling towers, which are the combined water and energy customers [15], heat is transmitted from the cooling system of a building by touch air and water. In terms of modeling and evaluating retrofit behavior, simulation of the energy system in the building is sufficient [1,36]. The heat exchanger networks have the cooling tower to deny electricity. Therefore, it is necessary to consider the importance of cooling and make-up water not just to maintain a finest working state, but also to mitigate adverse environmental effects [18]. It is necessary to allow the dissolved minerals to achieve a full concentration level to save water and processing chemicals. The concentration period is known as the blow-downstream concentration of a soluble product in the make-up stream [18]. The overall concentration period would depend on the water quality [33]. To order to improve water quality, chemical, physical and biological methods are used to address cool water issues, such as scale forming.Non-chemical treatment approaches such as ozone are considered as effective and environmentally friendly solutions for the use of maquillage water among all processes. Conventional water treatment methods for the cooling tower include the handling of microorganisms with additives, size, and pressure to eliminate impurities. Both these activities contribute to the operation and maintenance expenses of the cooling tower [9]. Integration of ozone water treatment with the cooling water system, selection of the saturation process, which decreases the concentration of water circulation of insolvent materials [43]. In the process sector, cooling systems are used frequently to cool machines and goods and move waste heat into the air [26, 39]. When demand falls year by year and severe contamination [10] rises, the water management and carbon control of the open water refrigeration system has attracted more and more interest. At present, the exploration of modern water sparing primarily incorporates two angles [20] utilizing water-sparing gear or water-elective innovation, (for example, air-cooling rather than water-cooling) and enhancing the structure and working parameters of the water framework in general, which is the focal point of this paper. The advancement of modern water frameworks, for the most part, incorporates two classes. (1) Water squeeze investigation [25] has a place with a realistic strategy and has the benefits of clear physical importance and basic arrangement. In any case, by and large, it is legitimate for a solitary contamination framework, and can't give the comparing ideal structure of water utilization frameworks. (2) Mathematical programming technique: Apart from the water squeeze examination, increasingly more research utilizes the numerical programming strategy [45,8]. For the improvement of water structures by logical programming, the proposed model can perceive the perfect transport of cooling water inside the framework and the perfect foundation zones and weight head of siphons required for CWS [7]. Broke down the attributes of water frameworks in the steel business, set up numerical models, and examined the connection between water restore and the patterns of COC [46]. System fluid cooling and vapor condensation are important functions of Chemical Process Industries (CPI). The most common way in CPI operations is to use a cooling tower, and the coolant used most frequently in most of this operation to eliminate waste heat. A typical large oil refinery handling 40,000 mt/hr condensation needs a soothing water power of 80,000 m^3/hr . For every barrel of crude oil refined, it is approximately equivalent to 25 barrels of water (CHEMICAL ENGG: PERRY HANDBOOK). In agriculture, energy can be saved by incorporating shift in behavior, changing and or upgrading facilities through water saving to reduce total water use and improve internal reuse [30]. Energy conservation can be achieved in factories. Resource optimization and expense minimization, exposure to actual use of resource and priorities are relevant. Reducing the use of commercial water is a way to tackle the global water issue, which accounted for 5-10% of total fresh water recycling use in 1999. The ventilation of industrial plants is a major part of all commercial water consumption. A fact sheet explains how electricity can be used more efficiently in output. Optimization for the water consumption of industry is significant because it can decrease local water shortages, while raising water availability and community relations, increasing productivity through intake of water, reducing waste water discharges and pollutant burdens, reducing energy usage and possibly manufacturing costs between 1987 and 2003. In addition to using the amount used in processing (UNESCO 2009), most factories create chemicals as a by-product of their industrial operations through effect of wastewater runoff and contamination capacity. Oil sediments, as the water temperature increases, dissolved water oxygen in the water reduces, low oxygen content in the water can be harmful to aquatic creatures and the major pollutants are pesticides, bacteria, heavy metals, synthetic and industrial material, oil sediments and fire. The cycle of concentration (COC) is defined as the concentration ratio of a soluble component in the blow-downstream to that in the make-up stream [28]. Changing cooling tower blow down from cold water side to hot water side in CW system for reduction in evaporation loss & heat load in CT (2018) [31,3]. Application of an environmentally optimum cooling water system design to water and energy conservation [38], reducing water consumption by increasing the cycles of concentration and considerations of corrosion and scaling in a cooling system. Water consumption of cooling towers can be reduced significantly by minimizing blow down in coordination with an integrated scaling and corrosion control program. Blow down minimized by increasing when concentration cycles increased. At his study research influence of sodium Hexa-meta-phosphate (HMP), 2-MercaptoBenzoThiazole (MBT) and ZnSO4 inhibitors on the control of corrosion and scaling for carbon steel and admiralty brass alloys at two concentration cycles in a power plant cooling system was investigated. The studies also shown HMP is hydrolyzed in low concentration intervals to orthophosphate. Orthophosphate is used as an intractable and alarming orthophosphate measure in the condenser pipeline, together with ion calcium, magnesium and iron ions. Reduced scaling and under substrate degradation, as well as maximizing the volume of ZnSO4 and MBT. If the concentration periods rose from 6.5 to 9, about $1.1\text{x}10^6 m^3/hr$ of water would be extracted per year while the cooling would be the same [12], Side Stream Filtration for Cooling Towers October 2012, Pacific Northwest National Laboratory [37,39,46], Analysis and Optimization of Open Circulating Cooling Water System. The model is used to determine the water temperature's impact on the makeup rate while the cooling power is inadequate. It is obvious that the CT evaporation rate is a main parameter for the models developed [47], respectively. Outdoor air conditions, inlet and exit levels of cooling water and the air-to-water ratio primarily affect the evaporation level.

3. Methodology

In the course of time, huge quantities of potable groundwater can be consumed in the cooling towers of complex industrial processes (refinery, thermal energy, Cement, paper and engraving).The refrigerant tower water use must be carefully regulated and minimized, if necessary, as the costs of its eventual testing grow larger and more and more involved. Operators responsible for comprehensive and dynamic network processes within the large plant may need to take certain factors into account, including downstream bleed use to achieve full site productivity and their specialist water treatment professional may be required to advice. . Cleaner development processes, including non-evaluation, evaluation and analysis approaches, innovative management strategies that can produce comparable outcomes. The entire tower water balance was tackled in order to optimize the energy preservation of any cooling tower. Evaporation, leakage, overflows and spill, stream down, wind age and device leaks are included in the water flows (losses). Some water outputs (evaporation and bleeding) are managed and essential for the proper operation of the system and the tower. Those controlled outflows must be optimized. Some outflows of water (overflow, drift, outflow, wind age, leaks and backwashing filtering) are unchecked. Uncontrolled outflows of water must be reduced or removed. A system's water output has to be improved and a system water analysis is the first step. KPIs (Key Performance Indicators) method was evaluated and documented and determined for key water parameters. A system must be designed for water production. The audit would help identify water consumption areas and future permit savings areas and formally recognize and report on refrigeration entry water quality. Water conservation and the output of the system at the required level should be carried out regularly.

Table 1: Audit the Tower Water Balance

Item	**Audit action**	**Comments**
Cooling tower	Check air inlets clear of obstructions and contaminated sources.	Any new plant/equipment, any material storage.
	Check for airborne debris Entering tower.	Any evidence leaves, litter, insects etc.? Air Inlet filters required?
	Check for strong wind exposure.	Screens required?
	Check drifts eliminators.	Installed correctly? Clean and unobstructed?
	Check tower casing.	Free of corrosion, damage and leaks?
	Check for evidence of splash out.	Any staining on casing or support platform?
	Check for evidence of leaks.	Check tower connections and system pipe work.
Cooling Tower Components	Checks fill situation & fixing.	Fill spotless & un-damaged. No block-age. Fill installed stage?
	Check H2O delivery scheme.	Nozzle in position, un-damaged, apparent?
	Ensure H2O delivery pattern over fill with fan at full speed.	H2O allocated uniformly over fill?
	Ensure tower fan at occupied speed.	Proof air magnitude. Several strange noise or vibration.
Cooling water pump	Check pumps connections.	Check and adjust any packed gland seal. Replace any leaking mechanical gland seal.
Cooling tower control	Check control system operation.	Tower fan cycle suitably? Inconsistent speed impels operating?
	Check tower water and air flow rates.	Within manufacturer/design limits?
	Check variable speed drive operation.	Critical frequencies locked out?
Cooling	Ensure makeup H2O meter.	
	Ensure blow-down meter.	

	Ensure blow-down is automatic &conductivity, managed.	
	Ensure blow-down solenoid valve & filter.	
	Ensure conductivity sensor.	
	Ensure COC for (C) Scheme.	
Water overflow	Ensure for some image proof of run over.	
	Discontinue pump & make sure for run over.	
	Ensure makeup valve setting.	
	Ensure scheme non-Return valve.	
	Ensure pipe work plan/amount.	
	Ensure equalizer pipe & valve for multiple tower schemes.	
Water management	Ensure H2O superiority constraints/KPI.	compute, estimate & proof;
		Conductivity of tower H2O (uS or ohms/cm)
		Conductivity of tower make-up H2O (uS or ohms/cm)
		Departure H2O Temperature C
		Scheme COC
		Chlorides (as Cl or as caco3) ppm.
		PH
		Total hardness (ppm as caco3)
		Ca hardness (ppm as caco3)
		Ma hardness (ppm as caco3)
		P-Alkalinity
		M-Alkalinity
		Some extra particular scheme KPI.
	Ensure scheme sieves.	Dirt free, redevelop or reinstate as requisite.
	Ensure sieve backwash.	Backwash meter mounted?
	Estimate tower H2O efficiency.	
Cooling tower management	H20 protection in H2O cure & safeguarding agreement?	contract
	Regular maintenance in place?	Record corrective & preventive maintenance
	Water audits carried out.	Record date of last
	Energy audits carried out?	Record date of last
	System optimized?	Is this system optimized?
	Site log book maintained? Documentation adequate?	Record date of last entry, License?

Table 2: Evaluating the Cooling System

Cooling system component considerations		
Material	**Water Quality Effects**	**Management Considerations**
wood	N/A	Defend from decline or chemical occurrence
Mild steel	High-total dissolved solids, suspended liquids, wood, strong and scale-susceptible to corrosion.	This ability is reduced by chemical water treatment. This capacity is reduced by higher flow speeds and regular flushing of heat exchangers.
Galvanized iron(Cu & Zn coating)	Vulnerable to erosion from high Melted solids and pH levels below 6.5or above 8.5.	Decrease series of attentiveness. Adjust pH with chemical treatment
Stainless Steel 304-SS	Chloride vulnerability to corrosion. When conditions exist for deposit-forming. Deposits of biomass may trigger fast flares. Corrodes of 200 mg / l chloride are usable under deposit conditions. Tolerates 1,000 mg / l on clean surfaces containing chlorides.	This risk is reduced by chemical water treatment. The durability of a safe oxide layer in stainless steel would benefit from maintaining a positive oxidant standard and rising the deposition of biomass. It is understood that nitrates that exist in recycled water at higher levels cause corrosion of Stainless Steel.
STAINLESS STEEL 316-SS	Compared to 304-SS but higher tolerances of chloride. 5000 mg / l of chloride tolerates. If there are requirements of deposit-forming. This tolerates clean surfaces with chloride amounts of up to 30 000 mg / l.	Similar to 304-SS.
Copper alloys	Ammonia and readily dissolved solids resistant to corrosion. The levels of ammonia above 0.5 mg / l as NH_3 can trigger cracking and corrosion and can cause copper alloy corrosion within deposits in biomass. Nickel alloys with copper (90/10 and 70/30) are crack-resistant.	Water action can diminish this potential. Copper corrosion inhibitors such as TTA (Tolytriazole) or BZT (Benzotriazole) in addition BBT (Butylbenzotriazole) reduce but do not totally eliminate cracking. BBT is greatest effective. Copper nickel alloys (90/10 and 70/30) are resilient to cracking.
plastics		Save clean besides free of bonds to avert clogging. Keep plastic film free of biomass buildup.

Table 3: Microbiological Growth Controls

Chemicals		
Chemicals *	USE	Recommended Max Concentration **
Phosphates*	Control steel scaling	20mg/l as PO4
Poly phosphate	Corrosion inhibitor & scaling	20mg/l as PO4
Sodium silicates	Corrosion inhibitor	100mg/l SiO2
Triazole (Aromatics)	Corrosion inhibitor	2-4mg/l
Molybdates***	Corrosion inhibitor	40mg/l as molybdenum
Isothialozin DBTP Amines****	Biological inhibitor	
Bromine, chlorine Biocides	Biological inhibitor	0.5mg/l

A lot of work at cooling towers water management has been done well by different researcher/scientist. Continuing the previous suggested modifications of past research, that has been recommended optional on this existing refinery, with little bit addition of Exhaust air. A High density polyethylene (HDPE)eleven feet angular cylinder mounted cooling coils as shown in Figure below containing inlet cooling water supply CWS and outlet cooling water return CWR flow of $10\,m^3/hr$ inside the coil after circulation pump line at normal make-up water temperature of $32\,C^*$ and pressure of $3.5\,kg/m^2$, model run at simulation program and output share physically at site to get the proof reading comparison and experiment research applied where 50% of evaporation losses recovered mathematically as expected to suggested modeling of Refinery where $108\,m^3/hr$ i.e. 50% condensate return to Hot water distribution channel to improve the CT efficiency due to recycle water temperature difference. This paper aims at discussing diverse feature of water consumption in an industrial sector & device a simplified tactic to reduce the water consumption. The blow down carried out from hot water side i.e. condenser outlet going to cooling tower to ensure water conservation. That will decrease total water flow in cooling tower, which in turn reduces evaporation loss in the cooling tower. As blow down, evaporation is directly proportional, depending on COC, both evaporation, and blow down will be reduced in the proposed plan. As TERLYN 1996 give perception of strong bonding element in makeup water to increase COC from 3 to 50 Cycles, The water consumption and blow-down usually change with the varying parameters such as quality and temperature. With the purpose of water saving, it is very important to optimize the operation strategy of water systems. The concept of cycles of temperature is proposed to evaluate the temperature relationship of various parts of the circulating cooling water system. A mathematical relationship is established to analyze the influence (co-influence) of the water temperature on the makeup water rate of the system under the condition of insufficient cooling capacity of the cooling tower.

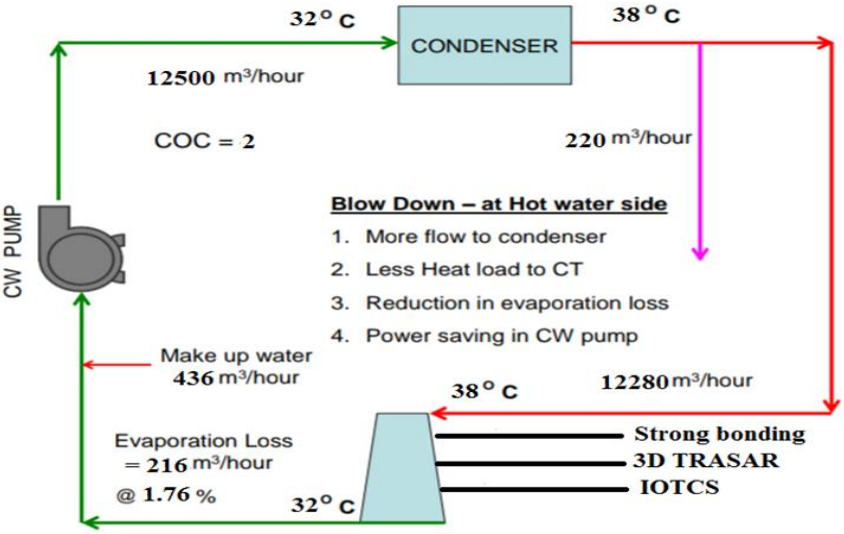

Figure 2: Proposed system of below down & IOTCS [28]

Three optimize areas based on the present data of existing target refinery, **COC optimize** -most excellent concert, **hold classification**- make sure procedure continuation verify and keep H_2O use, **executive sustain**- guarantee the running squad answerable and comprehensible aims, goals. H_2O is a finite resource. It is not possible to produce more water than what already exists on earth. The research based at some physical parameters changes e.g. chlorination replaced to IOTCS [33]. Understanding water treatment reports will assist in maintaining a water efficient cooling tower the overall purpose of a water treatment report is to provide a snapshot of the cooling tower operation and the effectiveness of the current water treatment to define the outcomes of a water treatment program. Suitable KPIs must be in place within the water treatment contract including tracking the associated performance (water efficiency), COC, own the system, management support.

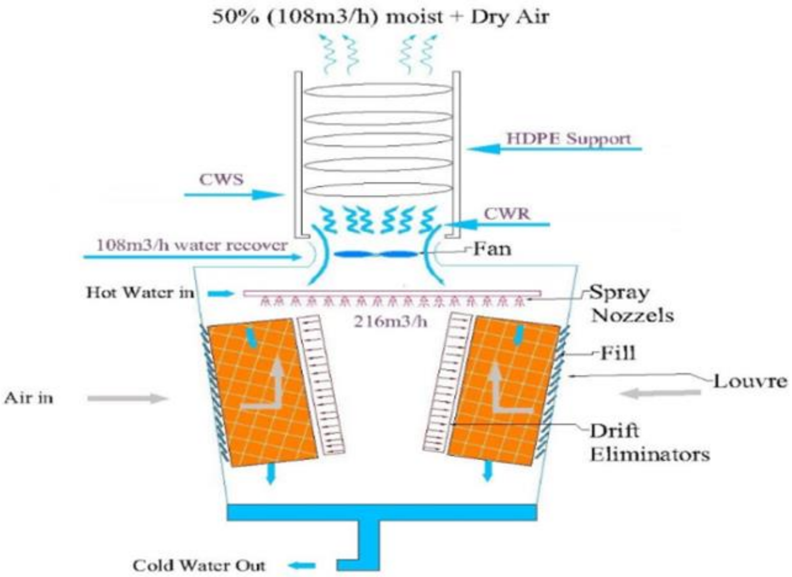

Figure 3: Advance Eco Approach (Angular Cylinder)

Water is cooled by air in a cooling tower the volume flow rate of air and the mass flow rate of the required makeup water are:

a- The mass flow rate of dry air through the tower remains constant $m_{a1} = m_{a2} = m_a$

but the mass flow rate of liquid water decrease by an amount equal to the amount of water that vaporize in the tower during evaporation must be made up later in the cycle to maintain steady operation

Applying the mass and energy balance

Dry air mass balance

$$\sum ma_i = \sum ma_e \qquad m_3 + ma_1 w_1 = m_4 + ma_2 w_2 = ma_2 = ma$$

$$m_3 - m_4 = ma(w_2 - w_1) m_{makeup}$$

Energy Balance

$$E_{in} - E_{out}\ \Delta E\, system = 0\, due to\, steady State$$

$$E_{in} = E_{out}$$

$$\sum m_i h_i = \sum m_e h_e \sin ce Q = W = 0$$

$$\sum m_e h_e - \sum m_i h_i$$

$$ma_2 h_2 + m_4 h_4 - ma_1 h_1 - m_3 h_3 = 0$$

$$ma(h_2 - h_1) + (m_3 - m_{makeup})h_4 - m_3 h_3 = 0$$

Solving for ma

$$ma = \frac{m_3(h_3 - h_4)}{(h_2 - h_1) - (w_2 - w_1)} h4$$

From psychometric chart

$$h_1 = 44.7 \frac{kj}{kg\, dry air}$$

$$h2 = 106.6 \frac{kj}{kg\,dry\,air} \qquad h_3 = h_f\,@40C = 167.53 \qquad h_4 = h_f\,@30C = 125.74$$

$$w_1 = 0.008875 \frac{kg\,water}{kg\,dry\,air} \qquad \frac{L}{G}$$

$$w_2 = 0.02905 \frac{kg\,water}{kg\,dry\,air} \qquad \frac{L}{G}$$

$$v_1 = 0.848 \frac{m^3}{kg\,of\,dry\,air}$$

Substituting

$$ma = 40 \frac{(167.53 - 125.74)}{(106.6 - 44.7) - (0.02905 - 0.008875)} 125.74 = 28.17 \frac{kg}{s}$$

The volume flow of air into the cooling tower

$$v_1 = ma v_1 = 28.17 \times 0.848 = 23.9 \frac{m^3}{s}$$

b-The mass flow rate of the required water is determine from

$$m_{makeup} = ma(w_2 - w_1) = 28.17(0.02905 - 0.008875) = 0.568 \frac{kg}{s}$$

Evaporation rate $m3 - m4 = 1.1 \frac{kg}{s}$

Heat dissipation $Q = m_3 C_w (T_3 - T_4) = 2.9MW$

For dew point ANTOINE EQ

$$P(T_{dew}) = \Delta p(T)$$

4. Methods

The present scenario the evaporation rate is 220m3/hr and which is reduced to by suggesting modification from cold side blow-down to cooling water return (CWR) hot side due to the following benefits [22].

For cooling Network water balance $F^{W}+F^{R}=F^{i}$ ________ (1)

For the cooling Tower Water balance $F^{I}=F^{L}+F^{V}+F^{P}+F^{R}$ _______ (2)

The control Equation of the system can be obtained by the following Water balance

$$F^{W}=F^{L}+F^{P}+F^{V} \quad \underline{\hspace{3cm}}(3)$$

For the Rate of make-up, leakage, blow-down and evaporation rate water balance equation

$$f^{W}=f^{L}+f^{P}+f^{V} \quad \underline{\hspace{3cm}}(4)$$

Here after, the reference to water quality means the cycle of concentration (N)

$$N=\frac{C_R}{C_W}=\frac{f^{W}}{f^{P}+f^{L}}=1+\frac{f^{V}}{F^{P}+F^{L}} \quad \underline{\hspace{2cm}} (5)$$

The make-up rate Vs COC can be written $f^{W}=f^{Y}N(N-1)^{-1}$ _______ (6)

But the Relationship b/w leakage rate, blow-down rate and COC obtained

$$f^{P}=f^{V}(N-1)^{-1}-f^{L} \quad \underline{\hspace{2cm}} (7)$$

If $f^{P}=0$ Zero emission

$$N=1+\frac{f^{V}}{f^{L}} \quad \underline{\hspace{3cm}} (8)$$

When cooling tower is presupposed to be capable to absolutely eliminate the equipment cooling load and therefore the egress temperature of the cooling tower

$t_R=t_n$ K = 1 cooling Index. At this point there is no requiring of temperature of the make-up water. Circulating water entirely cooled by the cooling tower for some reasons, cooling tower fouling or excessive outdoor air temperature resulting

K <1 $t_R>t_n$. When this ensue the inlet temperature of cooling network will continue to rise. However, it should be noted that in some industrial submission the cooling tower cannot cool the circulating water of the structure for some reasons.e.g. Heat exchangers declined or outdoor air temperature is too elevated. Rather than develop the cooling reason of the cooling tower, as an alternative, users take up fresh make-up water to reinstate part of circulating water. At that time, to keep the inlet water temperature of cooling network at the required rank. Since of the utilization of new water. It is vital to set up the connection between the make-up rate and temperature of make-up water and the circulating water so.

$$f^{W} = \frac{t_R - t_n}{t_R - t_W} \_\_\_\_\_\_\_\_\_\_ (9)$$

Then $Nt = \frac{t_R}{t_W}$, $\bar{Nt} = \frac{t_n}{t_W} = K\frac{t_R}{t_W} = K.Nt$ ___________ (10)

Nt=cycle of Temperature of Cooling tower outlet $\bar{Nt}$ = cycle of temperature of cooling network inlet.

Energy Balance Models

$$m_{w},_{in}\, Cp_{in}T_{in} - Q_{evap} = m_{w},_{out}\, C_{p_{out}}T_{out}$$

$$R = T_{IN} - T_{OUT} \qquad A = T_{OUT} - T_{WB}$$

Approach temperature and water flow rate the approach is more important than the water flow rate and the range in achieving a high driving force for cooling. This is because of the driving force become more limiting as the approach become narrow. Since cooling performance is influence by the water flow as well as other factors [23]. The evaporation rate is a function of water flow rate and temperature difference of cooling tower [22] evaporation rate is.

The water entering the cooling tower is

$$m_{w,in} = \frac{DisposedHeat}{C_P \Delta T}$$

Amount of evaporation depends on air flow rate, humidity of inlet air and humidity of cooling tower outlet air. Exit air humidity is related to water temperature and transfer area of packing. So it means evaporated water loss is not constant when design variables are considered flexible [24].

$$\frac{d_w}{d_z} = \frac{KaA_{fr}}{m_a}(w_{sw} - w)$$

The saturated humidity ratio at water temperature is [3].

$$w_{sw} = 0.622\frac{P^s}{(P - P^s)}$$

Cooling tower characteristic is given by Equation [21].

$$\frac{KaV}{L} = \int_{Tout}^{Tin} \frac{C_p dT_w}{(h_{asw} - h_{awv})}$$

The amount of water dm_{evapo} is evaporated; the evaporative loss forces an increase in cooling tower supply flow rate [21].

$$dme_{vapo} = m_a d_w$$

$$dQ_a = m_w dh_{fw} + h_{fw} m_a d_w$$

1 $E = 0.00175 \times Flowrate \times cycle ratio$

$$E = \frac{f \times R \times DT}{1000} \qquad were\, f = 0.65 - 0.85 \quad 1000 = approxlatentheatvaporation$$

$$E = DT \times Q \times \frac{0.2}{2}$$

$$E = 0.0085 \times 1.8 \times flowrate \times DT$$

2 Cooling tower capacity

$$(TR) = 500 \times DT \times \frac{Q}{12000}$$

At tower L/G ratio, definite cooling assortment approach perfect cooling range of cooling tower. Energy of air is divided into air via convection and evaporation, air convection is function of dry bulb temperature and evaporation is function humidity ratio of wet air moving from bottom to top of the tower. The effect of temperature ratio as a function of inlet wet bulb temperature, temperature ratio decreases with increases in L/G ratio this is due to increase in heat load which leads to lesser cooling range approach ideal range [29]. Evaporation loss is decrease with increase in air inlet wet bulb temperature T_{WBI} , while evaporation loss increase with inlet water temperature (t_{wi}), L/G changes in outlet water temperature (t_{we}) with respect to inlet water temperature (T_{wbi}) is less when compared to inlet air wet bulb temperature . Inlet air WBT has more effect on outlet water temperature than inlet water temperature

The size of cooling tower the number of transfer units (NTU)

$$NTU = hd\,Av\frac{L}{G} = f_{wi}^{wr}\frac{d_w}{w_{sw}-W}$$

$$NTU = hd\,Av\frac{L}{G} = f_{wr}^{wi}\frac{d_w}{w_{sw}-W}$$

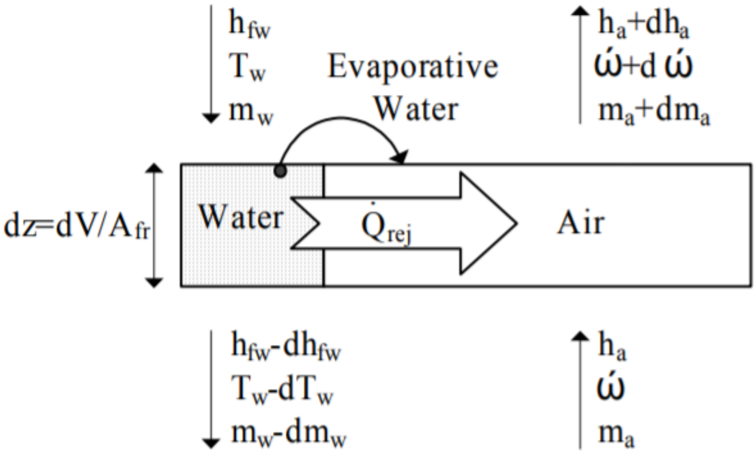

Figure 4: Mass and energy balance

Approach =outlet water temperature t_{we} -inlet air wet bulb temperature t_{wbi}

Approach is high at tower inlet air wet bulb temperature t_{wbi} when compared to higher inlet air wet bulb temperature t_{wbi} at same L/G ratio.

Water approach temperature increases with L/G ratio due to increases in heat load which leads to decrease in cooling range [13].

$$Effectiveness = \frac{Q_{act}}{Q_{\max}} \quad where\ Q_{act} = actual heat removed \quad Q_{\max} = \max imum heat removed$$

Air flow rate is expressed [13].

$$F_{air} = \frac{E}{W_{out} - W_{in}} \qquad Where\ w_{out} = outlet humidity\ W_{in} = inlet humidity$$

$$W_{in} = f\,(T_{wb} - T_{amb}), \qquad W_{out} = f\,(T_{in} - T_{out})\frac{1}{2}$$

$$T_c = C_c + O_c$$

Table 4: Design Data (Cooling tower Refinery)

Item	Description	Cooling Tower Refinery	Cooling Tower Fertilizer	Cooling Tower Power plant
1	Water circulation rate (gpm)	1500m3/h	30,000m3/h	55000m3/h
2	Hot water temperature (F)	38	35	40
3	Cold water temperature (F)	32	26	32
4	Wet bulb temperature (F)	30	29	30
5	Drift loss(%design circulation)(m3/hr)	20m3/h	60m3/h	110m3/h
6	No of fans	03	06	06
7	Evaporation loss (m3/hr)	220	528	968
8	Bleed(BD) (m3/hr)	200	528	7968
9	Make up water (m3/hr)	440	1056	1936
10	Price/Loss m3/hr	3.6	3.8	3.9

Table 5: Make up water current quantity

Sr.No	COC	Evaporation	Blow-down	Make-up
		t/h	t/h	t/h
1	2	220	220	440
2	3	220	110	330
3	4	220	73	293
4	5	220	55	275
5	6	220	44	264
6	7	220	36	256
7	8	220	31	251
8	9	220	27	247
9	10	220	24	244

Table 6: Make-up Water Proposed Quantity

Sr.No	COC	Evaporation	Blow-down	Blow-down savings	Make-up proposed	Make-up current	Make-up savings
		t/h	t/h	t/h	t/h	t/h	t/h
1	2	216	220		436	440	4
2	3	216	108	2	324	330	6
3	4	216	72	1	288	293	5
4	5	216	54	1	270	275	5
5	6	216	43	1	259	264	5
6	7	216	35	1	251	256	4
7	8	216	30	1	246	251	5
8	9	216	26	1	242	247	5
9	10	216	23	1	239	244	5
Total savings				9			44

Table 7: Make up water advance quantity

COC	Evaporation	Blow-down	Blow-down savings	Make-up Advance	Make-up current	Make-up savings
	t/h	t/h	t/h	t/h	t/h	t/h
2	108	108		216	440	224
3	108	54	54	162	330	168
4	108	36	72	144	293	149
5	108	27	81	135	275	140
6	108	21.60	86.4	129.6	264	134.4
7	108	18	90	126	256	130
8	108	15.42	92.58	123.42	251	127.58
9	108	13.50	94.5	121.50	247	125.5
10	108	12	96	120	244	124
Total savings			666.48			1322.48

Falling the evaporation loss in CT and to defend water in the CW structure. This suggestion recommend to fulfils blow-down of cooling water from hot water of CT i.e. after cooling net work and control of evaporation rate. By taking blow-down before it enters the cooling tower, the total flow to the cooling tower reduces by an amount equivalent to the amount of blow-down. As the evaporation loss in the cooling tower is directly proportional to the amount of cooling water flow, less water will evaporate in cooling tower. Because the hot water that removed as blow-down from hot water side before it enters the cooling tower, less water will evaporate in the cooling tower compared to present system of cold-water blow-down or the same operational performance. This leads to savings of water, this kind of water savings is very well applicable and appreciable in any kind of industrial plant irrespective of their unit capacity /size and the type of cooling tower.

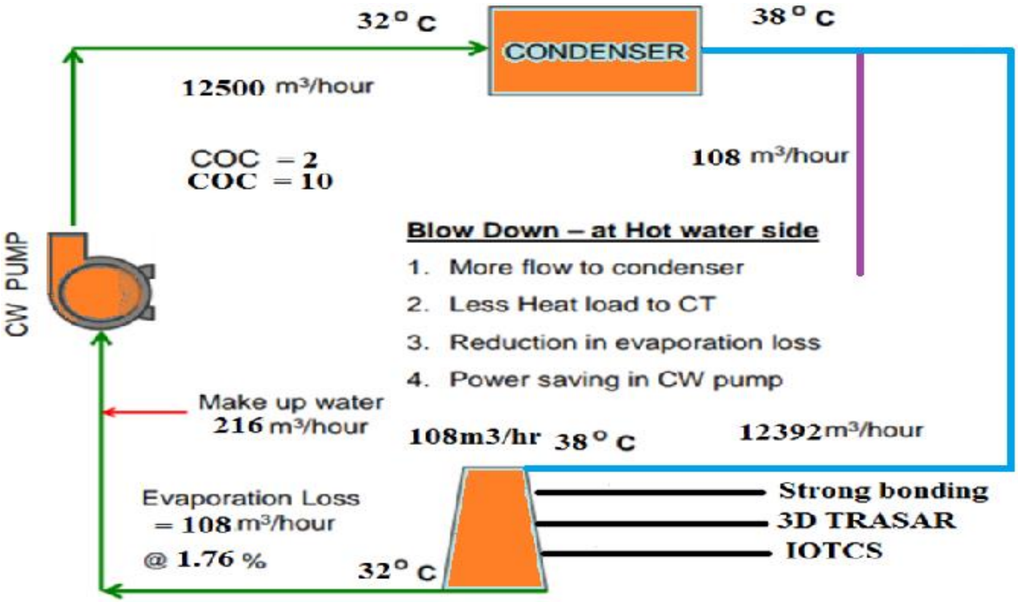

Figure 5: Advance System of Water saving (ECO-Design)

Table 8: advanced make-up water savings

SI.NO	COC	Blow-down water savings	Make-up water savings
		M3/h	M3/h
1	2		224
2	3	54	168
3	4	72	149
4	5	81	140
5	6	86.4	134.4
6	7	90	130
7	8	92.58	127.58
8	9	94.5	125.5
9	10	96	124
Total savings		666.48	1322.48
Savings charges@3.6		666.48+1322.48=1988.96x3.6=7160.256-Rs//h 7160.25x24=171846RS/m3/dayx365=62723790RS/annum	

Hence, significant quantity of water saved in a refinery by this uncomplicated amendment. The savings of make-up water is very significant at lower COC. In addition, the following improvements have visualized. Decrease in heat load of CT. Decline in expenditure of water. Reduce in water cost. Reduce in Cooling Water cure cost in channel. Reduce in water cure cost. Reduce in pumping cost of blow down water. Reduce in Cooling Water pumping power. Based on experience, it is found that, hot CW blow down water can safely replace cold blow down water without any process related difficulty in the applications.

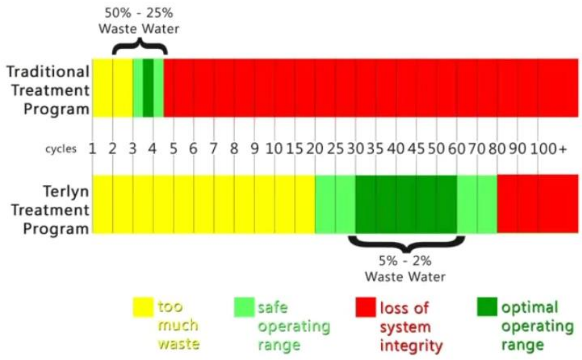

Figure 6: Operating range comparison

The advance approach applies at Exhaust of cooling tower as shown below Figure-13 where 216m 3/hr of evaporation losses controls by modification. A vertical cylinder of 11 feet containing circulation water supply after pump passing through cooling coil above exhaust air that contained condensed evaporation losses and approximately reduced 50% losses by this experiment as calculated in experiment mathematically. No evidence effect of exhaust air pressure and fan back pressure or any other consequences build up during physical experiment at site. Water saving targets 1988.96m3/hr achieves.

5. Results and Discussion

Related information, in this way, is separated from regular weight channels since components are confined on the outside of channel as opposed to entering to channel media. Which gives two advantages: (1) filtration can be accomplished down to 0.45 micron even on a perfect media bed on the grounds that the utilization of the extra fine sand media and (2) discharge necessities are short since particles are not caught endless inside the channel media. For a sludge that takes around 5 to 8 minutes, only about 50% of the designed front flow via a high-performance filter is needed, compared with 150% of the expected sands flow that needs 15 to 20 minutes. Such filters are effectively managed in a smaller system. High efficiency filters will process 18 gallons of water on a square foot of a media sheet, opposed to 8 to 10 gallons of normal pressure filters per square foot. The differentiation between filters can be very critical for mechanical room devices to be chosen.

Table 9: Relationship between makeup rate and COC graph

f^W	0.1	0.09	0.08	0.07	0.06	0.05	0.04	0.03	0.02	0.01	0
COC	1	1.25	1.5	1.75	2	2.25	2.5	2.75	3	3.25	3.75

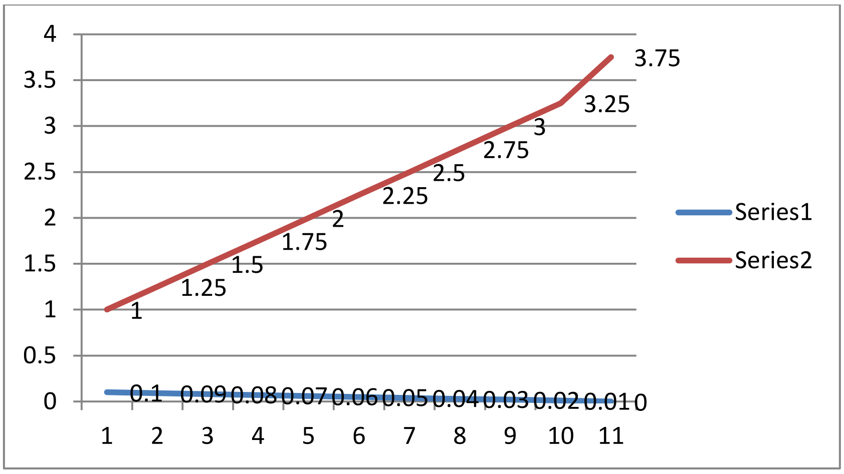

Figure 7: Relationship between water flow rate and COC

According to graphs lesser COC guide to upper makeup rate .this tendency suit extra visible when the COC is less than 2.that seen that increasing the COC is one of the significant techniques to shrink water utilization and cooling tower join with other tools to chill the cooling water to reduce the evaporation of water. The makeup rate will be reduced.

6. Status of Implementation

The scheme of cold side blows down and evaporation rate control has executed under 2types: Class-I: The proposed amendment has been incorporated for the forthcoming new industrial plants, which are below conduit / preparation phase. Class-II: Compulsory recommended for achievement of this suggested modification for all the running units has been issued; as such, these units are running with low COC, the prospective for water savings is elevated.

7. Savings Potential

It is approximation that by implementing the warm water blow down design all across Refinery, Power plant etc would result in makeup water economy of approx. million m3 per annum and Auxiliary power savings, which results into financial savings of ApproxRs. 627 million/year.

8. Conclusion

Advance study establish that by taking blow-down from hot side of cooling tower, reduction in evaporation loss and reduction in the water makeup to the CW system is achieved, compared to cold side blow-down. The proposed modification will be implemented across all industries to conserve water. The proposed modification may be taken up as a measure of conserving water and energy to promote sustainable environment for the present /future plants (Refinery, Fertilizer and Power Plant) located across the country.

- Use of hot side blow-down in cooling water system save max.of approx.1988 m3/hr of water compared to cold side blow-down system .

- The proposed modification has many advantageous in addition to saving in water like ,reduction in pumping power, reduction in CT heat load, water cost etc.
- The water saving potential is inversely proportional to the COC of the CW system, which varies from plant to plant.
- In refinery, there is a potential savings of approx. Rs.62.7 million/year. 62723790

Considering the total water consumption in one target industry, the water savings obtained by this advance method is very small in quantity. However, whatever savings in water consumption even in very small quantity is very much essential in country like Pakistan, where demand for water is huge and in many states (Sindh, Baluchistan) water availability is a major point of concern at present and tomorrow. Cooling tower consume a significant amount of water due to evaporation. Therefore make-up water is frequently used for replacing the evaporated H_2O. This make-up H_2O is usually cold enough to condense the evaporated water.

- The outlet air relative humidity is above 80%,which results to a significant water evaporation of about 216m3/h.
- The makeup water temperature is lower than the exhaust air dew-point temperature and so it has a good potential to condense the exhaust air moisture.
- Using the makeup water to cool the outlet air will result to a significant water savings about 108m3/h.

Main indicator at water reduction is COC &outcome calculated by model illustrate that make-up rate & blow-down rate of the scheme turn down with the increase of COC. The subsequently phase of my do research will be experimental substantiation of this practice.

9. Recommendation

The water management practices at industry is at top priority due to concept of water conservation in the region under PEPA Act 1997 but different cleaner production technology implementation is still lagging i.e.

- Chlorination replace by Ozonation
- Side filtration need to be improved by high efficiency sand filter.
- Internal/External Third Party water audit. Evaluation Plan.
- Water chemical non chemical and integrated approaches.
    a. It is further suggested to change the behavior of water blow-down from Cooling Water Supply to Cooling Water Return and most important the Evaporation loss may be reduced to 50% by following the research outcome model as suggested.
    b. Water charges proposed and revised suggested. Implementation, monitoring and audit evaluation is the responsibility of Law Enforcement authority. Status of implementation of modification suggested across all industry in the region of country under signatories conditions of globe.

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