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Waste Wash Water Recycling in Ready - Mix Concrete

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Abstract: ***In recent years, the awareness of the public on the environmental problems caused by producing large amounts of waste wash water during the process of manufacturing ready - mixed concrete has increased threefold. Hence, many nations across the world as well as global organizations have been imposing various laws and regulations in order to monitor and limit the emission of such waste and high pH value. Throughout the following study, the author evaluates the existing literature on waste wash water and the concrete ready - mixed concrete production around the world. The existing literature is compared, with various findings of different studies evaluated for their contribution to the topic and the field.***

Keywords: waste wash water, ready mixed - concrete, pH value

1. Introduction

It is true that water crisis has become a global issue in the last couple of decades as the human population increases and water resources remain scarce. The following issue negatively influences health, agriculture and food in various countries around the world. The use of water in construction and concrete production further affects water resources around the world, which countries have been trying to address through building plants for waste water treatment taken as a solution. Through these strategies, the above - mentioned issue could be overcome, helping the water consuming industries. (Ferriz-Papi, 2014)

One of the biggest industries consuming water is the construction industry by the opinion of many scholars as huge amounts of water are consumed during these processes. In particular, plants that produce ready - mixed concrete whereby it is used for producing concrete at around 0.5 ratio of water/cement, as well as spending a lot of water for washing the mixer drums of the truck every day. According to some estimates, around 1500 liters of water is utilized for a single truck in each day. (Paolini & Khurana, 1998) Taking into account that a single truck is able to transfer around 8 cubic meters of concrete where at least 1600 liters of water is used, this could lead to water cycling process to be insufficient where double amount of water could be consumed at the concrete plant.

In addition, when the trucks discharge the water, it could lead to local water source pollution and be dangerous because of alkali characteristics of the water. Therefore, both US Environmental Protection Agency and European Environmental Agency have adopted legislation that classify the waste of ready - mix concrete at 11.5 pH, making it a hazardous waste. (Sealey, et al., 2001)Meanwhile, certain studies have claimed that in recent years, the waste water from ready - mixed concrete has improved in terms of fresh water concrete manufacturing ratios. (Chatveera & Lertwattanaruk, 2009)

Considering the reasons given above, number of plants producing ready - mixed concrete have purchased and been using systems of water - recycling, so they can be reused for washing the trucks during the production of concrete. (Su, et al., 2002) Through this paper, the author aims to review the existing literature on ready - mixed concrete production and how water waste treatment is carried out in various parts of the world. The author considers different sources for an objective analysis of the current situation regarding this topic.

2. Literature Review

2.1 Concrete Production Waste Water in Uzbekistan

Before author reviews the existing literature, it was deemed appropriate to provide a little insight into concrete production in Uzbekistan. It is a double - landlocked country in Central Asia that faces significant water shortages. Additionally, the rainfall in a year is also very low compared to consumption levels in the country. (Gheim, 2010)Water supply per capita is also very low as the country's main exports remain to be agriculture, making up around 23% of the country's GDP. The water scarcity problem is further intensified through high rates of population growth not only in Uzbekistan, but also in neighboring countries of Kazakhstan and Tajikistan, where the main water sources flow from. It should be noted that the water resources stress continues to increase and the fact that around 45% of water supply of Uzbekistan comes from groundwater resources. (Djumaboev, et al., 2017) Uzbekistan's aquifers are utilized almost twice the rate of recharge, and also threatened by various pollutions including dangerous chemicals being improperly disposed, landfill sites seepage and over - pumping. This has been pushing the local government to seek new management of water supply through the uses of alternative water sources like waste water treatment.

Although not as much as the agriculture sector, concrete industry has also been consuming large amounts of water in Uzbekistan. In this industry, the consumption of ready - mix concrete for every cubic meter is calculated to be at 170 liters for mixing and extra 60 liters of water is used later on during the process of washing mixer trucks, equipment and concrete pumps. After the washing process, the waste water of washing is comprised of solid content that is high suspended, with dissolved solids being extremely high of equal or above 9000 mg per liter, while pH levels being equal or above 12 when it comes to alkaline and heavy metals. Hence, environmentalists in the country consider the waste wash water disposal to be major contributor of environmental issues both in Uzbekistan and the rest of the world.

Consequently, when plants that produce ready - mixed concrete do not dispose the waste wash water properly, it can pollute the local surrounding environment with heavy metals as well as high pH levels into the water sources in the country. (Abunqira, 2008)It is clear that number of studies have demonstrated the heavy metals' toxicity to be a big threat to the health of people, with concrete production heavily mobilizing the metals in the environment. (Jaishankar & Tseten, 2014)

While in developed and certain developing countries like South Africa and US many concrete companies recycle almost all quantities of waste wash water, Uzbekistan has not progressed in this matter as much. (Sandrolini & Franzoni, 2001)Here, many concrete companies engage in illegal dumping of waste water in the outskirts of cities because there are no proper government legislations, and very little attention being paid for recycling of concrete water waste. Certain companies even engage in mixing the demolition and construction waste together that results in hindering the recycling process. (Ghrair, et al., 2020)

One of the regular practices in Uzbekistan in terms of ready - mixed concrete is dumping/discharging of waste water wash into nearby sites of construction or landfills. (IWMI, 2015) The following is a big threat to the country's water resources and environment. It was mentioned above that the country already faces the challenge of water shortage, which severely affects plants that produce ready - mixed concrete due to fresh water being of high cost and improper disposal of waste water. (Hamidov, et al., 2016) Hence, the local government should focus on developing and implementing novel innovative solutions that could help both the industry and the local environment. If the government and the local businesses of ready - mixed concrete start using feasible, simple and efficient technologies that are applicable and cost effective, even the ready - mixed concrete production costs could be lowered. (Roy, et al., 2001)

The following literature review's expected outcome is inspiration for new solutions for the presented challenge, which should help the environmental impact of waste water from ready - mix concrete production in Uzbekistan. Additionally, the review should also present concrete proof of how certain plants have been successfully implementing waste water wash treatments utilizing feasible, simple and efficient technologies that are applicable and cost effective.

2.2 Ready - Mixed Concrete Waste Water Recycling

Recent studies have demonstrated that the results look promising when it comes to waste water recycling of ready - mixed concrete in terms of fresh water – concrete production ratios. (Chatveera & Lertwattanaruk, 2009) According to Klus et. al (2017), in mortar production, concrete plant waste water recycling partially replaces mixing water, which helps with reducing the harmful effects to mechanical properties. (Klus, et al., 2017) Their study illustrated that when concrete plants utilize waste wash water, it resulted in setting time to be reduced by 15 minutes and flexural strength could be increased with age of compressive strength equaling 28 days.

Another study that focused on waste water recycling of ready - mixed concrete plants illustrated that waste wash water samples had over 11.5 pH value, making this waste hazardous, and could not be disposed by the US and European legislations. (Tsimas & Zervaki, 2011) The study demonstrated that samples of water collected adhered by the standard specifications of EN and ASTM in terms of water used for mixing in the concrete production in the perspective of chemical properties, but none met the very strict specifications of Hellenic Standards. The study also confirmed that when waste water wash that is appropriately processes is utilized, concrete performance is not harmed even if they do not meet the Hellenic Standard demands. One might consider it ironic that Uzbekistan and other developing countries already have certain limits of using mix water from recycled water even if extensive treatment is not present while developed countries like UK allow businesses to utilize waste water wash even if they did not go through pre - treatment that is extensive. (Chini & Muszynski, 2001) Another study in China also studied the concrete plants, exploring their waste processing and potential re - use of waste water. (Xuan, et al., 2018) Number of plants that produce ready - mix concrete have been implementing washing - out systems, and they have also been using reclaiming systems, which help with the production of concrete slurry waste and reclaimed aggregates. Although the potential of re - using those forms of waste was drawn interest, principles and methods of those treatments' mechanisms have not been properly reported. The sustainable utilization of theirs is limited because of strict regulations, high cost, low rate of re - using, poor product performance and other management challenges. (Matos & Prudencio, 2020)

2.3 Review of Previous Projects

As aforementioned, number of studies have been carried out hose waste water is potentially used in concrete production, with several vital conclusions being presented along with certain mixed results being reported. For instance, series of tests that were extensive were carried out sampling, over 6000 mortar and concrete specimens that comprised of 68 water samples. (Abrams, 1924)The author concluded that any municipal or naturally occurring supply of water that is suitable for purposes of drinking is fit for utilizing for concrete mixing water. Even though the author did not use any wash waste water, the author reached a significant finding of various water types that contain impurities such as industrial waste water, alkaline sulphate water and marsh water were good enough when implemented in concretes and mortars. Their strength would still be above 90% of the control specimens' strength made utilizing pure water. (Abdallah, et al., 2017) However, mixing water algae was said to reduce strength and entrain air tremendously.

Another study that investigated mortar's sulphate resistance, workability, setting time and strength when recycled wash water was incorporated. (Borger, et al., 1994) In this case, the used aggregate – cement ratio was 2.75, while 0.485 was the water – cement ratio in mortars. The study stated that wash water age influenced the strength greatly, with around 20% increase. The general realization of strength increase occurred when mortars were using water that had around 8 hours of age, with the reduction of permeability and workability also being witnessed. Additionally, there was an increase of sulphate resistance. The above - mentioned effects were thought to happen because of mortar's increased cement content out of wash water present particles of suspended cement.

Meanwhile, the study of Selih et. al (2003) where recycled water of different batching plants of Slovenia were examined with CEM – I 45.2 - R cement and 0.4 w/c and 30 MPa concrete, the authors observed air and slump content reduction with fine particles level increasing. (Selih, et al., 2003)Contrary to Borger et al. (1994) 's findings, the authors stated strength had lost 10% of its power because recycled water was used, but water tightness had been improved. Meanwhile, the investigation of Sandrolini and Franzoni (2001) that explored the utilization of waste wash water among various plants of mid - size producing ready - mix concrete using mix water illustrated wash water mixture of 28 - day age had as much strength as a control mix. In this case, the used concrete mix possessed 0.57 w/c while cement was CEM II/A - L and 45.5 - R. They also reported water porosity and absorption reduction, which indicates that durability improvement potential exists when wash water is utilized.

It should be noted however that some recycled water could be not fit for utilization in certain concretes because of the presence of impurities and water source. This is the findings of Kuosa (2005) where he studied five kinds of water that contained detergents. (Kuosa, 2005)The author found that when recycled water had utilized 26 - 100% of mix mater proportions, the concretes' strength and setting time were not affected. However, spacing factor and structure of air - void had been adversely affected when it was used, rendering its influence within air - entrained concrete, with possible problem of durability arising when it came to resistance of freeze - thaw nature.

There were also mixed results when there was an investigation of sludge water usage as concrete mix water. In Chaatveera et. al (2009) 's study where they investigated acid attack, drying shrinkage, elasticity modulus, compressive strength's mechanical properties, temperature rise, slump and unit weight, 0.7, 0.6, and 0, 5 w/c concretes were utilized. The results indicated that the strength and slump were decreased when sludge water was used, but the fresh concrete's temperate and unit weight were not impacted. At the same time, when sludge water proportions were increased in the mix water, acid attack affected the weight loss and drying shrinkage increase.

3. Assessing suitability of recycled water for use in concrete

In the early days, widely employed traditional criterion to explore the mix water suitability was comparing whether its quality was fit to drink. Nevertheless, development of number of specifications in terms of acceptable limits of chemical impurities as well as effects of theirs on some concrete properties have emerged. (Aldossary, et al., 2020) The following criteria were put forth in ASTM C - 94 and ASTM C - 94 where 28 - day and 7 - day compressive strengths of mortars and/or concretes that had recycled water in them should reach around 90 percent of control samples' strength with distilled and municipal water. (Abunqira, 2008) When recycled water is present in the mixes, C - 94 allowance for final and initial sets deviations are 1.5 and 1 hour respectively. Meanwhile specified deviations of SANS 51008 should not exceed setting time's 25% within the control mix produced of distilled water. (Gheim, 2010)

Even though South African concrete industry of read - mix products practice recycled water use, and encourages environmental protection and water conservation interests, very little investigation has been carried out on how it affects concrete properties. (Xuan, et al., 2018) A study in South Africa investigated the quality of recycled water at a Gauteng plant of ready - mix concrete for determining the fitness of concrete water mixing. The tests were carried out upon hardened and fresh properties of concretes and mortars comprised of flow or slump, air permeability, compressive strength, total output of hydration heat, setting time and unit weight.

RMC operations generated waste water comes out of systems of truck wash, central mixing plant's washing, wash down of conveyors, waste water coming out of dust control of water spray kind and plant yard of ready - mix producing runoff of storm water. It should be noted that waste water quantity produced would vary from day to day as storm water runoff generated is in unpredictable amount. Nevertheless, the estimations indicated that when a ready - mix truck of 10 - cubic yard transports concrete, around 600 pounds or around 1 - 4% remain in the mixing blades and drum's inside. (Parker & Slimak, 1977)When the workday is over, residue concrete should be cleaned off of the ready - mix truck, and as per some estimates, around 150 - 300 gallons of water is used when residual materials of cement is being removed from a single truck's blades and drum. (Master Builders, 1988)

Moreover, when it is calculated on a plant basis, a single plant that produces ready - mix concrete could use up around 3000 - 5000 gallons of water per day when truck wash generated waste water quantity is estimated. Hence, it was calculated that a single country could use up around 1240000 gallons of water in a single year. (Borger, et al., 1994)Thereby, environmentalists always worry that waste water of concrete could contaminate ground and surface water bodies, which could consequently endanger the aquatic organisms' and people's well - being.

4. Disposal of Waste Water

It should be noted that currently countries dispose of concrete wash water through number of methods including using ready - mix plant's pit of concrete wash water for dumping, using landfills for dumping or even job - site dumping. (Low, et al., 2007) Hence, number of governments and international organizations have been working on adopting legislations and regulations that could oversee the dumping methods of dumping at plant yards and job sites, with a specific example being Clean Water Act of 1987. It should be mentioned that the following legislations are revised continuously to include water pollution sources like construction sites, yards of ready - mix plants and storm water runoff from them. For instance, in the state of Florida, the batch plants producing ready - mix concrete are only allowed to discharge water waste to the state's surface waters, because of the rainfall created conditions that exceeded 24 - hour, 10 year designated hydrologic event. (Matos & Prudencio, 2020) In layman terms, the easiest and most economic variant of concrete wash water disposal became illegal, except when weather conditions that are rare occur because of environmental effects. Other businesses also use the practice of dumping the wash water from concrete into plant's mechanical reclaiming units or wash - out pits.

In the meantime, facilities of batch plants have been using different configurations of operational nature for controlling pollution that is linked to waste water, including systems of water reuse, facilities for retention/detention of storm water and settling ponds. (Gholamreza, et al., 2015) Meanwhile, aggregate and settling recovery processes also utilize wash pits. When it comes to unlined ponds, they are utilized for effluent percolation and evaporation towards ground water. In terms of facilities which has many suspended solids removed through tank or basin sedimentation, there is fairly clear water coming out of the treatment system that has 100 ppm level of suspended solid.

Nevertheless, material that is dissolved will stay at high levels of 550 - 2500 ppm range, while the drinking water of normal range has dissolved solids at a 100 - 500 ppm. (Pierce, 1994)On an operational level, the control systems and treatment functions are as follows: The settlement (washout) pit collects the truck wash process generated wash water. Next, aggregate recovery and settling process uses the washout pit. This is followed by discharging or reuse of wash pit generated supernatant to retention pond or truck washing respectively. The retention pond also is home for the discharge of wash down from conveyor, water sprayed dust control generated weak wastewater and site generated storm water run - off. The effluent that is combined then permitted to percolate or evaporate into the ground via spray fields, percolation pond or holding ponds. (Yadav & Dharmendra, 2018)

5. Alternative Solutions

There are number of alternatives put forth by scholars and practitioners around the world with one of them being usual way of concrete wash water disposal utilizing systems of chemical stabilizing. They were introduced way back in 1988, known as stabilizing admixture systems, which Master Builder Technologies have been marketing with the trademark Delvo. There is also Recovery model marketed by Grace Concrete Products as well as Fritz - Pak Mini - Delayed set marketed by Fritz Industries. (Kus, et al., 2017) When these admixture systems are used, they avoid the need for removing wash water out of truck drums of concrete, while also permitting for reuse of wash water in more concrete mixing. (Holway, et al., 2011).

In this case, dosage depended has the addition of admixture upon waste water amount present within the concrete truck's drums as well as on the desired time span for water reuse. Consequently, the process of hydration is stopped momentarily by these admixtures, with present cement being literally put into a "dormant" condition. (Abed, et al., 2017) With the interruption occurring in the hydration process, the hardening of cement into concrete within the wash water cannot occur and would not affect the concrete truck drum's inside. Through this way, there is a calculation of stabilized water into concrete mix, with more volume of concrete being available for mixing inside the concrete truck.

When this method of admixture is used, it creates the advantages of environment associated issues decreasing. As a result, labor is saved in terms of disposing of residual wash water, while freight costs and equipment costs are reduced when the need for disposing of wash water is eliminated, leading to less requirement of expensive recycler/reclaimer units. In addition, there would be less maintenance costs needed to chip set concrete from drums of mixer in case less water is used in each load. (Vaiciukyniene-Palubinskaite, et al., 2021)

At the same time, one should not forget to note that there is a high cost for utilization of admixture stabilization. Therefore, it can be concluded that recycling the waste water has far more benefits. For instance, when the plant uses the reclamation system's waste water, fresh concrete could be the target of using that batch of water. It is no secret that waste water reclaimed from concrete has been in use for number of years for the processes of fresh concrete production and washout purposes. (Aldossary, et al., 2020) There have been number of studies carried out that explored the fitness of using waste water coming out of concrete that is ready - mix during the production of concrete dates back to 1970s. Hence around 50 years ago, comparative tests were conducted by Ulman (1973), where waste water used out of city water and mixer washout pits were evaluated. The results demonstrated that those samples had no impact on admixture requirements, mixing water content, air content and strength. (Ullman, 1973) However, this practice had the main concern of now having enough knowledge in terms of how it influences the waste water's impurities and how it would affect concrete properties.

Similarly, Meininger (1973)'s study focusing on reusage of cement slurry and wash water in ready - mix concrete demonstrated that no significant influence of wash water was present on drying shrinkage and strength of concrete. However, in comparison to a study by Borger (1994), Borger investigated wash water impact on properties of concrete utilizing the mortar cubes produced through wash water of ages between 1 - 48 hours. (Meininger, 1973)In this case, tap water made up the control mortar. His study stated that when wash water is aged up to eight hours, it can be utilized successfully to produce fresh concrete, which would result in equal or higher concrete strength compared to tap water made concrete.

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