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Quantitative Investigation of Potential Contaminants of Emerging Concern in the water: A Focus at Swaswa Wastewater Stabilization Ponds in Dodoma City

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Effluents released from wastewater stabilization ponds are re-used for irrigation while sludge is directly applied to agricultural lands as potential fertilizer. However, some treatment schemes are less efficient on the treatment, and not designed for removal of contaminants of emerging concern (CEC). Thus, the current study investigated the occurrence of CEC and physicochemical characteristics of Swaswa wastewater stabilization ponds (SWWSP). Sample partitioning followed by full scan mode GC/MS analysis for screening of CEC was adapted. It was observed that both influent and effluent from SWWSP had a significant amount of CEC such as metronidazole in the range of 0.065-0.104 ppm. It was further observed that physicochemical analysis before and after partition had insignificant differences among EC, salinity, pH, ammonium, and TDS. Nevertheless, turbidity and DO were significantly affected by the partitioning process. The presence of metronidazole poses unclear environmental threat that requires immediate intervention since this chemical and other CEC have no local and international guidelines and do not fall under routine monitoring activities.

Key words: Swaswa; Contaminants of Emerging Concern; Metronidazole; Physical Parameters; Chemical Parameter; Wastewater Stabilization Ponds;

Introduction

Contaminants of emerging concern constitute a class of non-regulated chemical and microbial contaminants such as pharmaceuticals, personal care products, water disinfection by-products, algal toxins and enteroviruses existing in the aquatic environments [1]. CEC are characterized by lack of standard guidelines for their environmental monitoring, they require modern technology for their identification as they exist in ultra-level amounts and they have recently gained scientific attention due to their health and ecological presumed risks. Among health effects of CEC include endocrine disruption, resistance against certain types of medication [2] hormonal interference in fishes, genotoxicity, carcinogenic in lab animals, and immune toxicity [3-5]. While military sites, domestic, clinical, industrial and municipal wastes are common sources of CEC [6, 7] in most scenario ammonium salts in the WWSP signify the presence of human excretes than from agricultural runoffs. Ammonium salts as fertilizer favor the growth of unwanted weeds that compete with other potential flora and fauna in the uncontrolled ecosystem. The physical and chemical composition of a Wastewater Stabilization Pond (WWSP) affects the efficiency of wastewater remediation treatment. For example in anaerobic treatment, if the pH goes below 5 due to excess accumulation of acids, the process is severely affected. Shifting the pH to 10 upsets the aerobic treatment of the wastewater [8]. The presence of severe colloidal material increases turbidity that affects the amount of sun and oxygen reaching microorganisms, which interferes with aerobic treatment of wastewater. The dissolved oxygen determines whether a system is aerobic or

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anaerobic, in order to predict the biological process taking place for transforming the biodegradable organic contaminants present in the wastewater.

It is a common practice to irrigate vegetation such as vegetables and cereal crops with effluents from WWSP, unknowingly transferring water contaminants from contaminated effluents to the soil and therefore plants. In addition, the majority of untreated sludge is applied directly to agricultural land as a source of nutrients without consideration of transferring contaminants from WWSP to the farming land. The dangerous phenomenon of bacterial resistance, due to the presence of residues of antibiotics in environmental matrices, poses a real threat not only to the ecosystem but also to human health and this needs special attention. Therefore, this article focuses on the investigation of physicochemical composition and the occurrence of CEC in order to reveal the current status of Swaswa wastewater stabilization ponds and proposition of appropriate future interventions.

Materials and Methods

Study area

Swaswa ward as indicated in Fig. 1, is 5 km from Dodoma city, Dodoma urban lies between 60° 00' and 60° 30' South and 35°30' and 36°02' East, covers an area of 2769 km^2 of which 542 km^2 are urbanized. Apart from the population size, where the majority relies on onsite sanitary, others rely on Swaswa wwsp for wastewater sanitary. Not all population is connected to wastewater sanitary pipes; rather they depend on private tankers. DUWASA is responsible for the supply of domestic tap water and management of wastewater.

Yet the climate is characterized by a long dry season lasting between April and early December and a short single wet season occurring during the remaining months with an average rainfall of 570 mm and about 85% of this precipitation fall in between December and April. Wastewater management does not pose a challenge compared to the wet region of Tanzania such as Dar es Salaam, possibly due to dryness and small population size.

Sampling and sample collection

Swaswa WWSP consists of four ponds, where only a set of two ponds are in operational. Eight wastewater samples were collected from eight different sampling points as indicated in Figure 1, by using clean 1-liter amber glass containers. The tap water sample was analyzed in order to establish characteristics of primary sources of Swaswa wastewater while distilled water was involved as a laboratory blank. Prior to sample collection, all apparatus and sampling bottles used were thoroughly cleaned with tap water and then rinsed twice with distilled water before drying. While in the field, each individual sampling bottle was clearly labeled for identification. It was followed by rinsing each container twice with respective wastewater to be collected and filling them nearly to the mark. All samples were immediately, placed in the dark cool jar for transportation to DUWASA water laboratory for analysis.

Before sample preparation, 50 mL of each wastewater sample was taken in a separate well-labeled amber glass bottle with a screw cap and transported to Chemistry Laboratory of the University of Dodoma for further analysis. All reagents and chemicals used in this study were of analytical grade from Sigma Aldrich, Germany. Standards solution of UV-Vis spectrophotometer was used for the analysis of NH_4^+ ions present in water according to APHA methods [9].

From each 50 mL samples, CEC was extracted from samples by using liquid-liquid extraction. The organic phases obtained via partitioning with dichloromethane were air dried under inert conditions to dryness. Prior to analysis, each sample was reconstituted with dichloromethane to 1 mL before auto-injection into QP2010 Ultra Shimadzu GC-MS, (Manufacturer: Shimadzu Europa GmbH Albert-Hahn-Str. 6-10D-47269 Duisburg) for identification and quantification of some CEC, as summarized in Fig. 2.

Data quality and consistency

Sample collection, handling, preservation, and analyses were done by following standard procedures recommended by the American Public Health Association (APHA) [9], which ensure data quality and reliability. In order to ensure the precision, all measurements were made in triplicate and validated by using the spiking experiment. The recovery obtained in the spiking experiment was 90 - 110%, which was within the accepted specifications [9]. Interpretation of numerical data obtained from this experimental work was done using Origin Pro software Manufactured by Origin Lab Corporation,One Roundhouse Plaza, Suite 303 Northampton, MA 01060 UNITED STATES. The quality of water at the sites under study was evaluated by comparing the obtained numerical data with that of Tanzania Bureau of Standards (TBS) [10] and WHO [11] guidelines for data comparison.

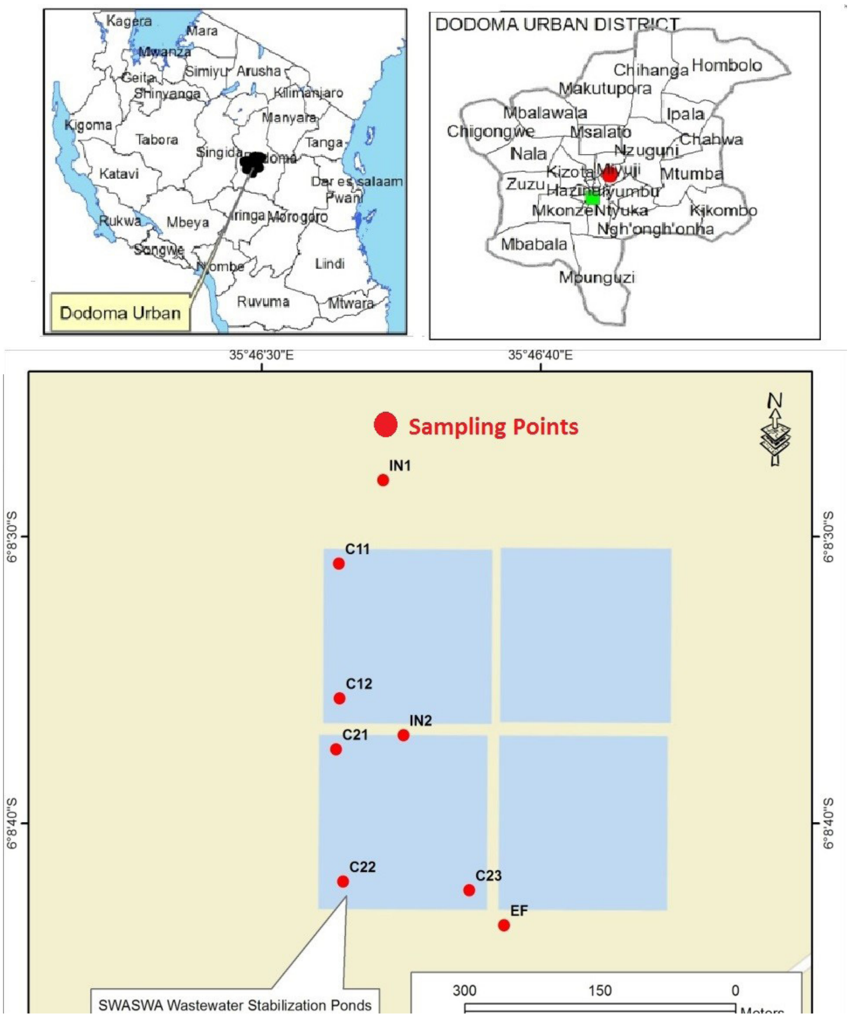


Fig. 1. Dodoma Map Showing Study Area

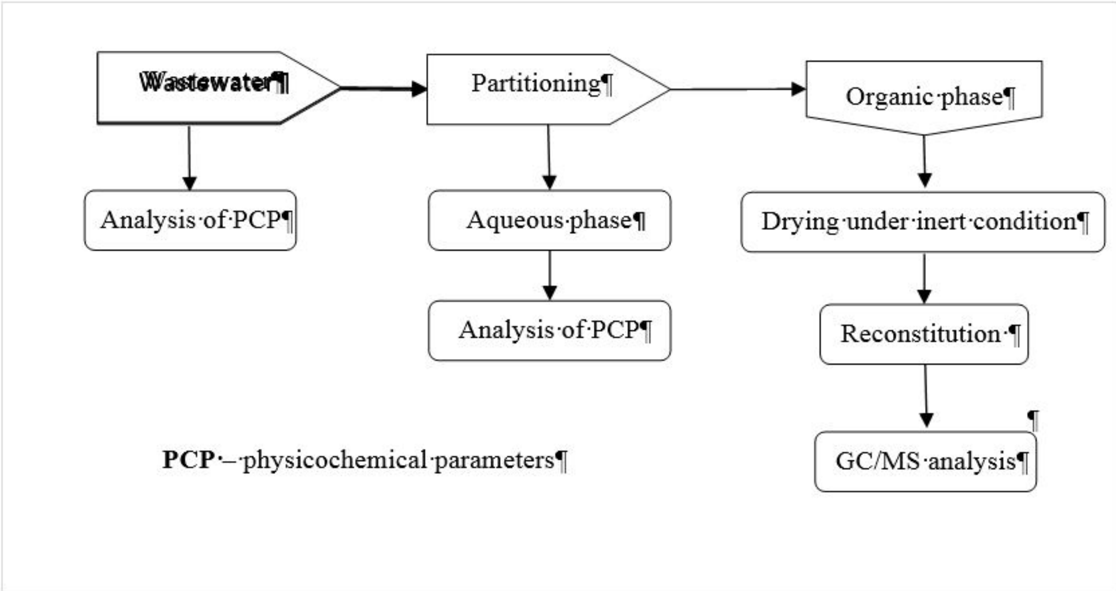
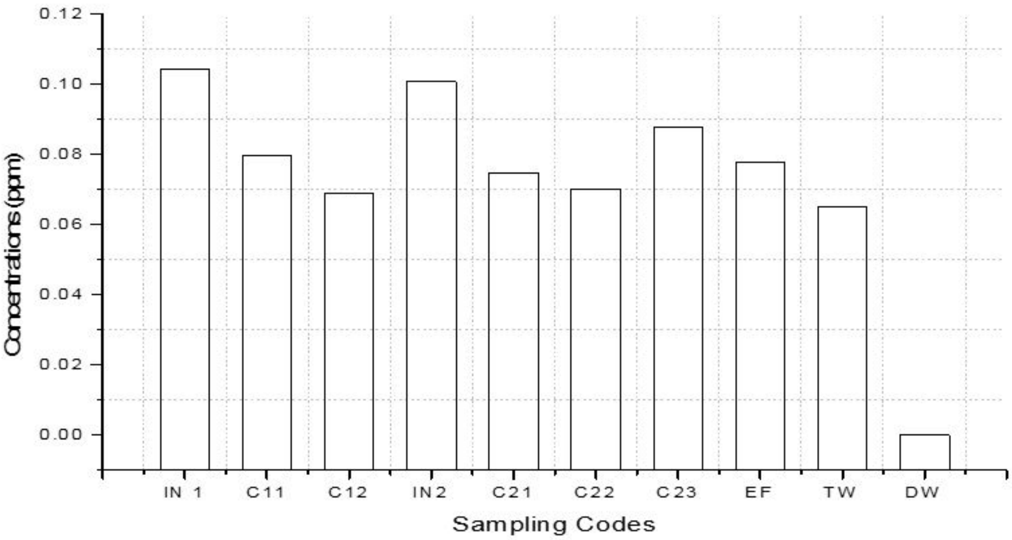


Fig. 2. Analysis Flow Chart



Key: IN1=Inlet to the pond 1, C11=First point in pond 1, C12 =Second point in pond 1, IN2 =Inlet to pond 2, C21 =First point in pond 2, C22=Second point in pond 2, C23 =Third point in pond 2, OUTLET =Point releasing effluents, TW=Tape water, DW=Distilled water

Fig. 3. Variation of Metronidazole Concentration

Results and Discussion

Contaminants of emerging concern investigated in this study included pharmaceuticals such as paracetamol, cetirizine, and metronidazole. Only significant amounts of metronidazole as presented in Figure 3 was obtained with a maximum concentration of 0.104 ppm. These results indicate a higher amount of metronidazole as compared to 0.0024 ppm [12], where they analyzed water from Msimbazi River in Dar es Salaam.

Santos (2010) reported about the continual entry of pharmaceuticals into the environmental compartment and addressed their physicochemical properties may have significant, long-term effects on the stability of ecosystems [13]. Although metronidazole can have metabolites such as [1-(βhydroxyethyl)-2hydroxymethyl-5-nitroimidazole and 2-methyl-5-nitroimidazole-1-ylacetic acid] and glucuronide conjugation as a result of primary side-chain oxidation, this study did not analyze them. However, note that both the parent compound and the hydroxyl metabolite possess in-vitro antimicrobial activity. Thus, the presence of this drug indicate the possibility of creating strain that is resistant towards this drug as it is distributed to the aquatic environment [2]. A study by Kristiansson et al. (2011) reported aquatic sediments to be a special matrix within which genetic transfer and recombination occurs. Antibiotics used in other anthropogenic activities may be retained within these sediments, which acts as an interface for a multifaceted and vibrant community of microorganism facilitating the transfer, maintenance, and dissemination of MGEs [14]. However, antibiotic resistant has become a global public health concern, because organisms that cause infection are becoming resistant to most of the prescriptional antibiotic treatment [15].

Turbidity

The turbidity of Swaswa WWSP before and after partitioning was significantly different, as presented in the Figure 4. This might have been contributed by the fact that most of turbid causing materials were organic in nature; therefore, the whole process of partitioning pre-concentrated them. These findings revealed that the conventional treatment method at Swaswa was effective in reducing turbid causing material from 730 to 214 NTU, which is within acceptable limits of 300 NTU as recommended by WHO [11]. Turbid causing materials especially organic types has a tendency of adsorbing organic contaminants and transport them.

Electrical conductivity and Total dissolved solids

The electrical conductivity and total dissolved solids presented in Fig. 5 and 6 are even parameters with similar properties and therefore are counter-parameters. These parameters were less affected before and even after the liquid-liquid extraction process. This was because electrical conductivity is determined by the number of dissolved ions in the water, which nearly all ionic inorganic compounds remained in the aqueous phase after partitioning. It was observed that the EC of influent (2260 μS/cm) was lower than the EC of the effluent (2320 μS/cm) possibly due to continuous accumulation of ionic compounds in the sludge thus affected the overall quality of wastewater effluents. Similar results were reported by Parsa et al [16] who investigated the physicochemical characteristics of raw and pretreated wastewater from Esfaham Composting Plant (ECP), Iran. Raw wastewater had low EC as compared to pretreated wastewater.

Values of TDS up to 1000 mg/L of TDS can be tolerated while corrosion may also become a problem with high TDS levels. Since these findings noted that effluent had a TDS value of 1136 mg/L, this was nearly close to tolerable values, yet technical intervention is needed to ensure that TDS value of effluent meets WHO recommended limits [11].

The salinity obtained before and after partitioning had insignificant difference despite a small concentration gradient from influent to effluent. Yet the obtained results presented in Figure 7 ranging from 0.49 to 1.34 ppt were within acceptable limits of 2.1ppt according to WHO. A study conducted by UNESCO found that at salt contents of one percent in the population of key organisms is responsible for the removal of nitrogen, phosphorus and organic compounds are affected. The nitrification process, which is carried out by ammonium and nitrite oxidizing bacteria, was decreased by 20 to 30%. In addition, phosphate accumulating organisms, responsible for the removal of phosphorus, were found to decrease by 70% at a salinity of one percent [17–19]. Therefore, the presence of salinity in the water should not be neglected. The analysis of the amount of ammonium ions only involved samples from the inlet and outlet of the ponds in order to establish the difference between the influent and effluent. These findings revealed a substantial decrease in the concentration of ammonium ions from 113.25 ppm to 45.0 ppm. Despite the decrease, yet the effluents had a higher value of ammonium ions than the WHO permissible level of 10 ppm [11]. The investigation of effects and accumulation of ammonia on growth performance indicated that ammonia and nitrite accumulation in aquaculture tanks could significantly reduce survival, growth performance of *L. vannamei* with hepatopancreas damage.

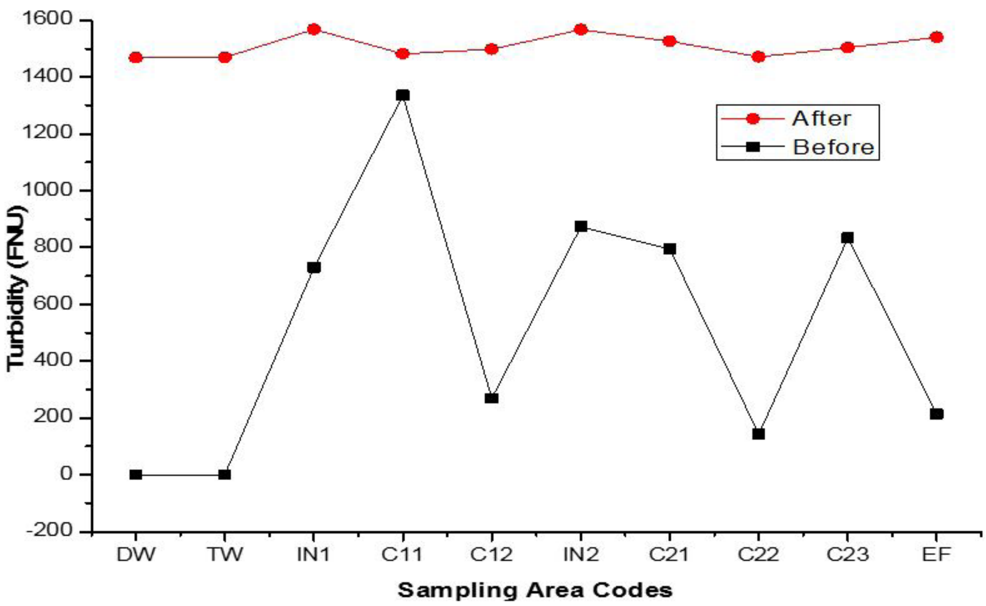


Fig. 4. Turbidity Variations Before and After Liquid-Liquid Extraction

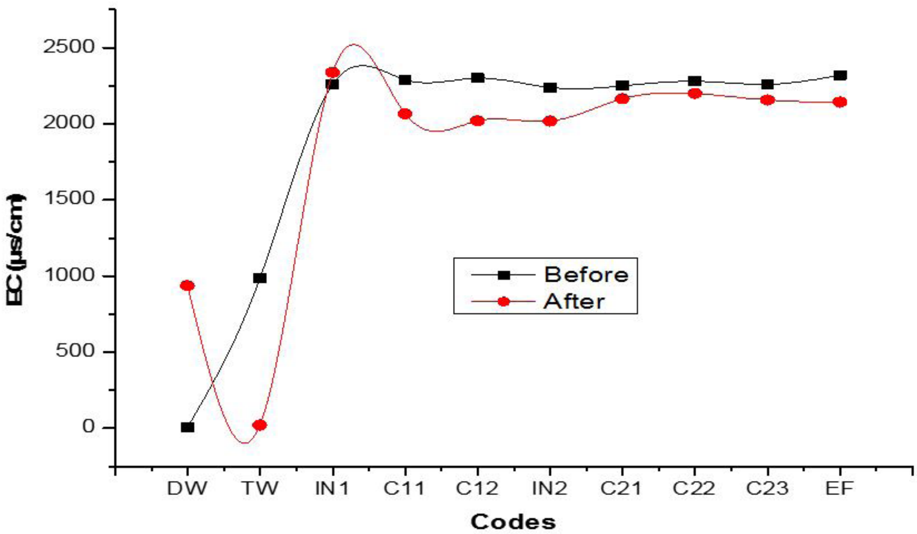


Fig. 5. Electrical conductivity Before and After Liquid-Liquid Extraction

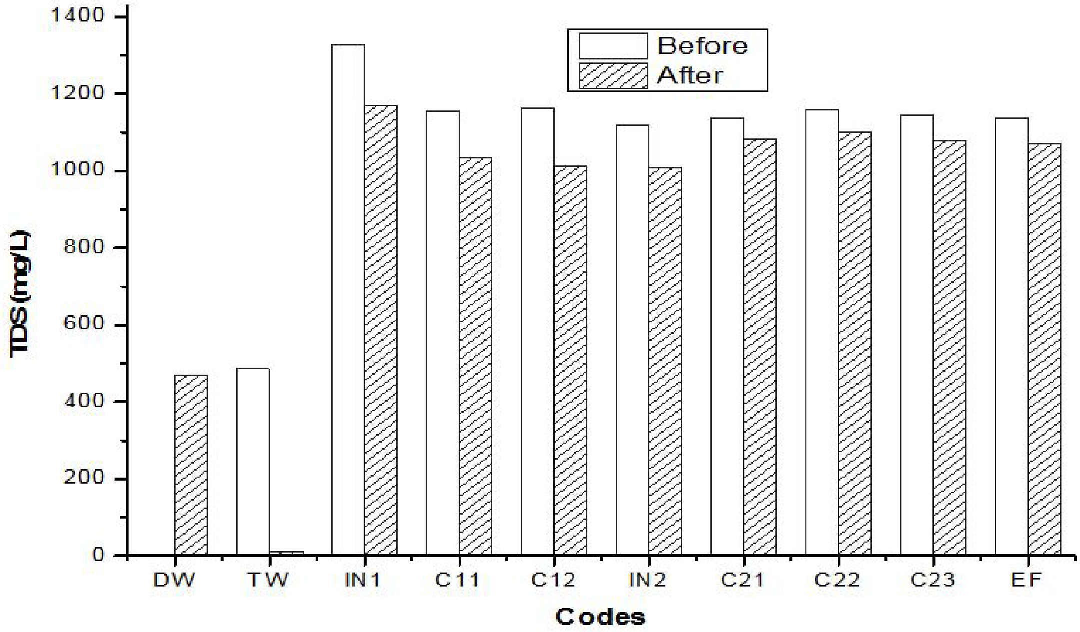


Fig. 6. Total Dissolved Salts Before and After Liquid-Liquid Extraction

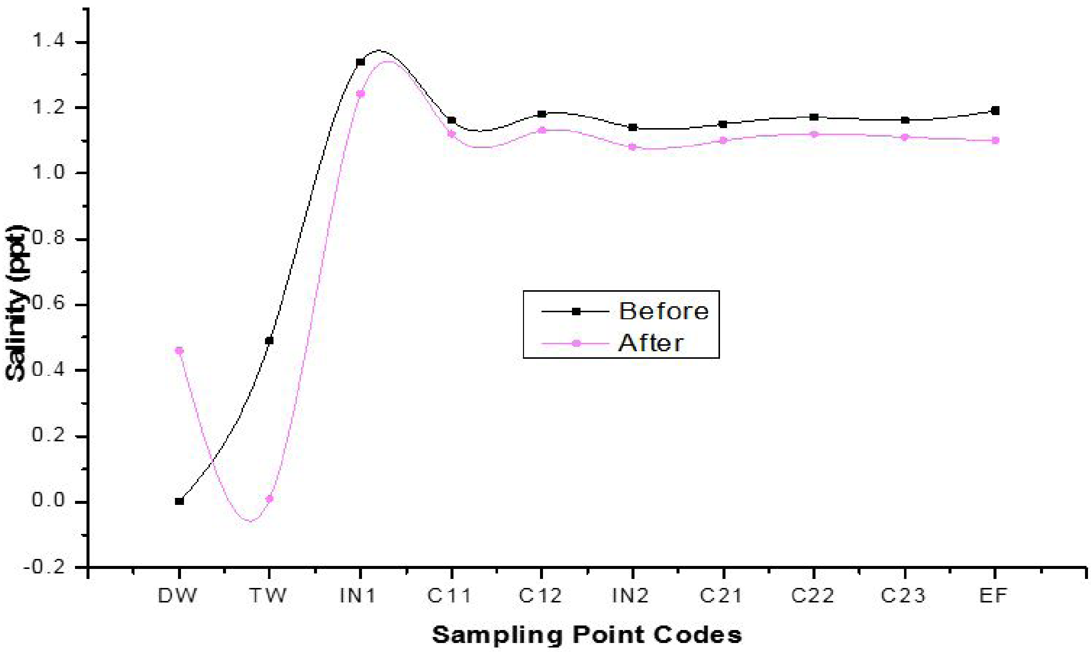


Fig. 7. Salinity Change Before and After Liquid-Liquid Partition

Therefore, ammonia and nitrite accumulation may significantly impact shrimp production in intensive aquaculture system [20]. This effect can be similarly linked to the survival experience of the organism found in the WWSP.

Dissolved oxygen refers to the amount of oxygen gas dissolved in the water. High water temperature allows less dissolution of oxygen in the water as compared to cold water, while the volume of moving water determines the overall amount of transported dissolved oxygen in the water. High DO value favors and support all kind of aquatic life. Contrarily DO value less than 5 mg/L induces stress to aquatics. This study revealed that tap water and distilled water had DO values of 4.22 and 4.85 ppm respectively, which is an indication of good quality as presented in Figure 8 [21]. Contrarily, all sampled points except effluents had DO values less than 1 ppm thus not suitable for life support. However, the DO value obtained from effluents i.e. 2.77 mg/L was significantly elevated compared to values obtained from the ponds possibly due to sufficient aeration and oxidation of wastewater.

This in another way shows that the conventional water treatment process at Swaswa was effective in taking care of dissolved oxygen. Patel et al conducted a study on the impact of discharge wastewater effluent on the Physico-chemical qualities of receiving watershed in a typical rural community obtained DO in range of 7.5 – 11.22 mg/L which is suitable for aquatic survival [22].

Conclusion

The conventional wastewater treatment system at SWWSP had an average efficiency range of 10.80-70.70% in taking care of pH, salinity, turbidity and TDS. Despite of this efficiency, TDS and EC remained above TBS and WHO recommended limits. Apart from the quantified amount of CEC, a gradual concentration gradient between influent and effluent was observed due to continuous adsorption and deposition of CECs together with sludge, thus sludge becomes a secondary source of CEC. Indeed, the presence of CEC at SWWSP is certain; there is a need to review policies that govern wastewater treatment, reuse, and management of contaminants of emerging concern so that effluents released to meet quality requirements for environmental safety.

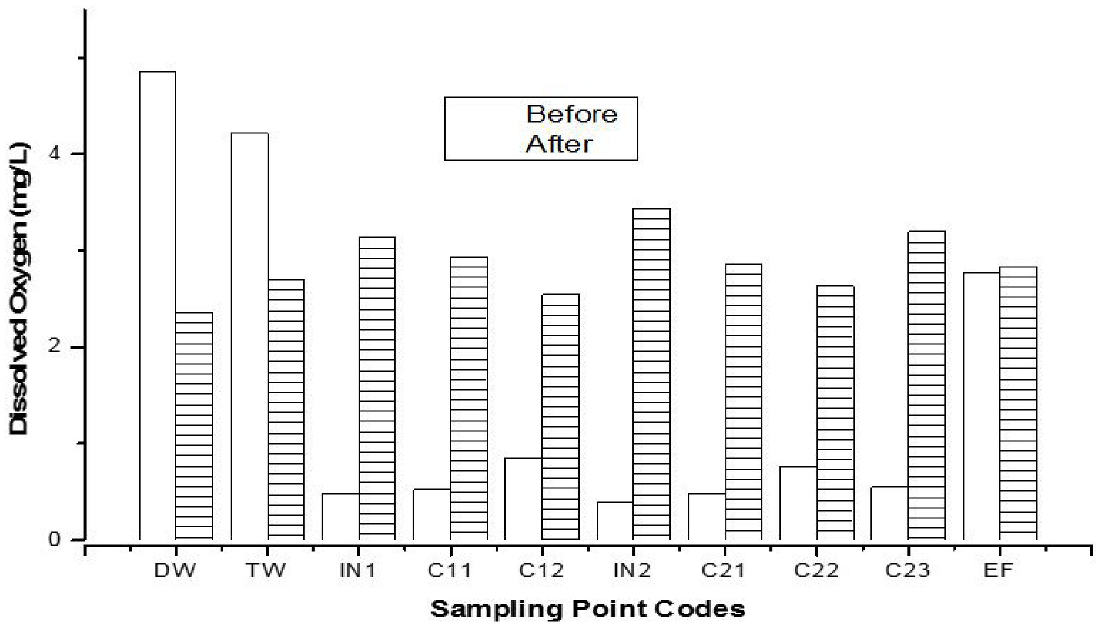


Fig. 8. Dissolved Oxygen Before and After Partition

Conflict of Interest

We declare that there is no conflict of interest in this research/article.

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