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قسم / ماجستير إدارة المخاطر



عنوان البحث

Effect of Exceed Sulfate Concentration Regulation Limit (150 mg/l) in Industrial Wastewater Discharged to Industrial Wastewater Treatment Plant: Western Region of Saudi Arabia

تأثير تجاوز حد تركيز الكبريتات (150 mg/L) في تصريف المياه العادمة الصناعية إلى محطة معالجة المياه العادمة الصناعية

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Introduction:

One of the most important environmental problems faced by industries is the management of waste. The chemical industry is a major source of wastes that can be harmful, dangerous, poisonous and life-threatening. Proper management of waste helps in recycling and reuse of the available resources, which helps in saving money and energy. The industrial wastewaters are difficult to treat because of the significant variation in characteristics of different industries. Specific treatment methods may be required for particular industrial effluents.

Sulfate ions are present in natural waters and industrial effluents of the chemical and metallurgical industries. Sulfate anion (SO_4^{2-}) is not considered to be toxic; however, high sulfate content in discharge water can result in an increase in the salinity of receiving water (Nariyan et al., 2018). The high concentration of sulfate in discharge water can also influence the permanent stratification of the receiving water, hence disturbing nutrient and oxygen cycles (Boehrer and Schultze, 2008). Therefore, the industrial wastewater with high sulfate content are required to be treated prior to being discharged into the environment.

Treatment of wastewater is a major step in preventing the pollution of water resources. The process uses to remove pollutants such as metals, debris, microorganisms, and biowaste from the wastewater. After treatment, the treated industrial wastewater (or effluent) may be reused or released to a sanitary sewer or to a surface water or to irrigation system in the environment (wikipedia,2024).

The Industrial Waste Water Treatment Plant (IWWTP) with its upstream situated collecting network from western region industries. The design capacity of the IWWTP is equal to 48000 m³/d. IWWTP consist THREE treatment stages which is Primary stage to remove settleable solids, Secondary Stage (biological treatment) to removing soluble organic matter solids that escaped primary treatment and finally Tertiary treatment to specification and to treat wastewater for public water systems.

Research Problem:

Local Regulatory body for Environmental regulation authorized for Western Region set a limit for Sulfate concentration that discharge to Industrial Waste Water Treatment Plant (IWWTP) is 150 mg/l. Based on current data that discharge from our chemical company is between 350 mg/l to 650 mg/l depend on internal process that discharge wastewater quantity which considered a clear violation on Environmental Regulation Requirements.

Importance of the Research:

The importance of this research is the assessment of the effects of an increasing influent sulfate concentration on the Industrial Waste Waters Treatment Plant (IWWTP) treating principally petroleum refining wastewaters, with particular attention to the biological processes for removal of organic compounds (Chemical Oxygen Demand/Total Organic Carbon) and Ammonia compounds: nitrification, denitrification and aerobic Chemical Oxygen Demand (COD) removal.

The Goal of Research:

To identify the possibility to increase the concentration of Sulfate from Western Region companies from 150 mg/l to 800 mg/l without impacting the Industrial Waste Water Treatment Plant (IWWTP) process efficiency, piping construction and irrigation system regulation

Research Question:

What is the consequences of high Sulfate concentration to Industrial Waste Water Treatment Plant?

Is it effect the biological treatment?

Is it impacting the construction of piping?

Is it effect irrigation system regulation?

Research Hypotheses:

The increasing of Sulfate concentration up to 800 mg/l for all Western Region companies having a relationship to violate the Irrigation System regulation (outlet results) for Industrial Waste Water Treatment Plant (IWWTP) and affect condition of constructed piping and kills the bacteria in biological treatment system.

Previous Studies:

1- Process inhibition by sulfate salinity

High salt concentrations are detrimental to bacteria. Salinity causes osmotic stress, ionic toxicity (improved membrane permeability and ruined cellular structure due to cations replacing Ca^{2+} in the cell membrane), oxidative stress (increase in intracellular reactive oxygen species), cell dehydration, plasmolysis (shrinking of the cytoplasm due to the diffusion of water out of the cell when salt concentration is above 10 g/l) and direct inhibition of many enzymes resulting in the loss of cell activity and death of micro-organisms (Lefebvre and Moletta, 2006; Zhao et al., 2013).

Most of the studies found in literature about salinity inhibition are related to NaCl that is considered the standard salt for this topic. However, Campos et al. (2002) tested three salts with different anions and the same cations (Na_2SO_4 , NaNO_3 and NaCl) and found similar inhibitory effects on nitrification autotrophic biomass. Differently, for heterotrophs bacteria, which are also in the biological section, chloride ion appears to have a higher inhibiting effect than sulphate ion (Pernetti and Palma, 2005). That being said and taking into account outcomes of the previous study about effects of chlorides, which indicated that no major evidence of nitrification inhibition was found in literature when considering chloride concentration up to 1,500 mg Cl/l, it can be deducted that, no significant inhibitory effects are expected for nitrification and denitrification, at SO_4^{2-} concentration up to 800 mg/L.

2- Favorable conditions for Sulfate-Reducing Bacteria (SRB) growth

Sulfate-Reducing Bacteria (SRB) are bacteria capable of sulfate reduction using CO_2 and H_2 as carbon source and electron donor, respectively (autotrophic SRB) or using organic matter as unique substrate with regards to heterotrophic SRB (Cassidy et al., 2015). Typical substrates are amino acids, sugars (e.g. fructose, glucose, etc.), long-chain fatty acids, aromatic compounds (phenol, etc.), volatile fatty acids (e.g. acetate, formate, propionate, butyrate, lactate), alcohols (e.g. methanol, ethanol, etc.) and hydrocarbons (Ollivier et al., 2007, Hao et al., 2014), whereas the major end-product of SRB is hydrogen sulfide (H_2S), a toxic compound for bacteria, aquatic life and humans (Hao et al., 2014) :

In some wastewater treatment facilities SRB are present in complex treatment scheme for Chemical Oxygen Demand (COD) and/or SO_4^{2-} removal with optimal COD/ SO_4^{2-} ratio for COD removal of 0.6/1.2 and with ratio of 2.4/4.8 for sulfate removal (Hao et al., 2014). In other biological processes SRB can be a danger, instead. In fact, information from the technical and scientific literature suggests

that an increase in sulfate levels in the influent of a Biological Nutrient Removal (BNR) plant can create favourable conditions for the growth of Sulfate-Reducing Bacteria (SRB) in basins where oxygen is not present, such as pre-denitrification and post-denitrification units. Moreover, SRB are able to tolerate molecular oxygen (Manz et al., 1998) and therefore aerobic basins (nitrification and flotation units) do not pose a concern for the survival of these bacteria in the biological process.

The possible presence of SRB in wastewater treatment facilities has been shown by Manz et al. (1998), who found a SRB from 0.5 to 8% of the total cell counts within all stages of an activated sludge process in Germany. Since these bacteria tolerate temperatures between 5 and 75 °C (optimum temperature values of 28 - 32°C), salinity up to 12% and a wide pH range (5.5/10) (Hao et al., 2014) SRBs represent a possible threat for any Biological Nutrient Removal (BNR) plant because, if present, they produce H₂S, that is toxic to nitrifying bacteria and possibly to nitrate-reducing bacteria

However, even though it is clear from the literature that anoxic conditions are favourable for SRB because these bacteria grow on the same substrate (soluble biodegradable COD) of Nitrate-Reducing Bacteria (NRB) and the coexistence of the two bacteria need to be demonstrated at the operational conditions of the IWWTP. In general, competition on the same substrate can result in coexistence or exclusion of the slow-growing microorganisms (SRB in this case). In order to investigate the possible presence of SRB a modelling approach is required in this research to simulate possible scenarios of increased sulfates in the influent.

Research Methodology:

Gathering data of Sulfate concentration is essential to start the research, the data will be gathered from Industrial Waste Water Treatment Plant (IWWTP), Regulatory body and two major contributor in order to assess of peak of Sulfate routed to IWWTP. In addition to first step, it's important to assess the Sulfate load within internal IWWTP. After that, the method of interpretation will be used for and it's constituted of three steps:

- Dynamic simulation of SRB growth.
- Minimum population sizes for species conservation.
- Magnitude of the possible impacts.

Lastly, Identification of expected degradation mechanisms is important to ensure proper material used in case of Sulfate concentration increased up to 800 mg/l.

Ways of Research:

Study the impact of Sulfate concentration with current situation which is range of 350 mg/l to 650 mg/l and slightly increase the concentration with close monitoring with any deviations observed to treatment system, piping, bacteria and outcomes Sulfate results. In addition, the history data of all stages are very crucial for the study in order to set proper and logic recommendations to achieve Regulatory requirements.

Tools:

Mathematical model is a system of differential equations that simulates biochemical phenomena in a real system, in this case the activate sludge system. Once the mathematical model is defined it must implement by a calculation software capable of solving differential equations. For that purpose, AQUASIM software, which is characterized by a strong technical and scientific validity will be used. It is like the use of spreadsheet applications to calculate/solve design formula of activated sludge system.

Research Limitation:

- Lack of previous research in terms of impacting of high Sulfate concentration to Industrial Waste Water Treatment Plant (IWWTP) process, piping and results as well.
- Poor cooperation with Industrial Waste Water Treatment Plant and Regulatory body to provide the historical data of Sulfate Analysis Results.
- Enforce local regulatory body to follow the new study recommendations.

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