Optimal Design of Wastewater Collection Networks Based on Production Rate of hydrogen Sulfide (h_{2^s})

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ABSTRACT: Unfortunately, nowadays, like the sewage collection network water supply systems just based on hydraulic parameters (quantity) are designed. The quality of wastewater produced, while that in adverse condition is very efficient. H2S production given that the relationship is in direct proportion BOD5 waste more time on the network will be more Barely also increased and this is related to hydraulic parameters. Must therefore between wastewater quality and hydraulic parameters of a relationship can create the best system design is achieved. In tropical cities due to high temperatures during the year chemical reactions are accelerated, the rate has been rising, especially H2S gases increased, destroyed sewage collection network and had to be seen along most of sewage collection networks already the end of the project did not have favorable conditions caused great financial burden on their maintenance will be contrary to the sustainable development.

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Introduction:

Corrosion and Unpleasant Odors Produced By Wastewater Collection Networks, Especially in Tropical Regions Have Caused Great Economical and Health Damage. These Issues Require That in order to Prevent Huge Waste of Money, appropriate Solutions Should be Presented to Prevent these Problems. h_{2^s} production of Wastewater Collection Networks is Based on Amounts of Organic Sulfur Which is Derived From Proteins, Inorganic Sulfur From the Sulfur of From Detergents. These material in the Absence of Dissolved Oxygen, Produce h_{2^s} Gas Due to the Activity of Sulfate Reducing Bacteria. Because of Turbulence, this Gas Enters Headspace Sewers. Humidity and Oxygen are Need for the Oxidation of H_2S by Sulfur Oxidizing Bacteria, and as a Result, Produced. This Acid Corrodes Concrete by Dissolving its Calcium (fig.1). We know that the Amount of h_{2^s} in Excess of The Standard Level Will Cause Health Problems and Great Financial Costs, so it Must be Investigated And Estimated. The Basis of Most Prevention and Control Methods is Prevention From h_{2^s} Production, or After it is Produced, the Oxidation Should be Carried Out Prior to Its Entry Into the Headspace of the pipe. in this Way, it Will Be Controlled. However, the Main Discussion of This Research is About Presentation of a Proper Method to Design Wastewater Collection Networks Given the Hydraulic and biological Parameters in Which We Could Significantly Reduce or Minimize The Amount of h_{2^s} Production. But Nowadays Design process is Only Based on Hydraulic Parameters. During the Investigations, We Observed that There Were Several Mathematical Models in This Regard Which We set as Our Main Criterion for this Research.

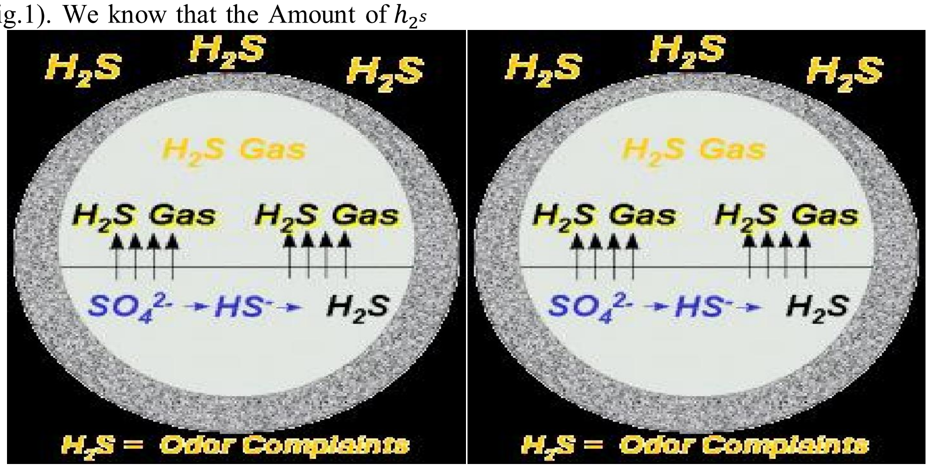

Figure 1. h_{2^s} Produced From the Surface of Wastewater Rises

As you see in (fig.1), h_{2^s} Produced From the Surface of Wastewater Rises, and is Mixed With Headspace Air of Collection Networks and Sulfuric Acid is Formed.

There Fore, The Greater The Concentration of h_{2^s} is, More Concentrated Acid Would be Produced and Corrosion Would be Greatly Exacerbated. next, We Will see That These Conditions Depend on Hydraulic and Biological Parameters of the Flow.

Research Background:

That Wastewater Collection Networks in Our Country Have Not a History, Applying Both Effective Hydraulic and Biological Parameters Has Not Been Considered in Design and Maybe the Only Solution is taken to be the use of Oxidizing Materials Which They put Into Sewers, But This Method is Not Just Engineering Method. However, Due to Higher Levels of Health and Increasing Advance in Science, Further and More Comprehensive Studies are Required. Outside Iran, (Pomeroy) in 1970 Did Research in the Field of the Formation of h_{2^s} and Corrosion Phenomenon Which Were Affected By Factors Such as Bod (Biological Oxygen Demand), Temperature, Slope of Sewer Lines. Ratio of H/d, and Flow Rate, Another Important Research That Can be Noted Is Related to England Water Company in Britain. This Company _Which is One of the Largest Water Companies in England And Wales_ Covers 27500 KMS, Which Supplies Wastewater Collection Network For a Population Amounted to 5/8 Million People. In This Network, There are 28300 KMS of Sewer, 3904 Pumping Stations, and 1578 Refineries. Due to the Flatness of Ground and Corrosion Conditions, Extensive Research Has Been Carried Out Using Chemical Materials, Natural and Artificial Ventilation, oxygen Cylinders, Liquid Oxygen and Ozone. Another Study on Applying Chemical Materials to Prevent Production of h_{2^s} Has Been Carried Out By Mary and Smitz in Which the Suggested Amount of Hydrogen Suggested Amount of Hydrogen Peroxide and Chlorine Required For Oxidation of Each Part of h_{2^s} are 1/5 and 25_170 Parts By Weight, Respectively. According to Another Similar Research By ben and Scott, the Amount of Chlorine Required Has Been Reported 150 (MG) Per Liter. However What Can be Seen From Used Resources is That Actually in Most Parts of the World, Especially Developing Countries, This Design Process is Not Considered, and This Means High Financial Charges For Maintaining Wastewater Networks.

Problem Statement:

Raw Sewage (Wastewater) Includes Large Amounts of organic and Nonorganic Materials Many of Which are Useful for Micro_ Organisms. Microbial Transformations Begin With Compounds of Organic Materials in Wastewater Network. During This Transformation, Amounts Of Organic Materials are Eliminated, and it Can Be Said That Collection Networks, Them Selves, Act as a Wastewater Treatment System. Dissolved Oxygen, Ammonia, Sulfate, And Organic Materials are Constant Compounds in Wastewater, While Nitrogen is Among Those Substances that are not Found(or can be Found in Small Amounts) in Household Waste. In the Gravity Sewage Collection Networks, h_{2^s} Production is Increased When The Flow occurs in Pipes Slowly and Aeration in the System is Low or Weak; That is, h_{2^s} Production is in Anaerobic Environment; However, h_{2^s} Production has a Direct Relationship With Temperature. In Addition,in Wastewater Collection Networks Part of The Network May be Designed Under Pressure. In The Case of Main Pressure Pipes, The Main Cause of h_{2^s} Production is Retention Time More Than 1-2 Hours, and in Pressure Pipes With Small Diameter, The Main Cause of h_{2^s} Production is the Mass Attached to the Walls of The Pipe. While in Main Pipes With Large Diameters, the Main Cause of h_{2^s} Production Is the Fluid Inside the Pipes. Given That Other Design Parameters are constant, These Effects Can be Presented as a Connection Between Pipe Diameter and The Amount of h_{2^s} Production,Which can be an Applied research.

Also, Biological Activity in Bed Load(De Posited Materials) in Wastewater Network Can be an Important Factor in h_{2^s} Production. However, We Should Know That When we Want to Include Biological Parameters, Industrial Waste water is Very Important Since Industrial Waste water Includes Large Amounts of Organic Materials And Sulfur That Are Very Effective in h_{2^s} Production. Calculation of The Concentration of Poisonous h_{2^s} Gas and its Acidity is of Great Importance. H2o Based on Chemical Equilibrium is Converted to Sulfur.

$$H_2S \leftrightarrow H\overline{S} + H^+ \leftrightarrow S^{-2} + 2H^+$$

Chemical Equilibrium Established in The Above Relation has a Strong Association With Ph. Ph in Wastewater is Typically Between 6/6- 7/2. In This Range, Chemical Equilibrium Between h_{2^s} and $hs^-$is Very Sensitive. A $\overset{\Delta}{\rightarrow}$ph=./2 Change in This Distance Causes a Change of About %30 in The Amount of h_{2^s} Concentration Production. Accordingly, The Distinction Between hs^- and h_{2^s} is Not so Clear. Calculation of Chemical Equilibrium Between hs^- and h_{2^s} is Expressed According the Following Relation:

$$* H_2S \leftrightarrow H\overline{S} + H^+ \quad (2)$$

$$* k = \frac{|H\overline{S}||H^+|}{|H_2S|} \quad (3)$$

h_{2s}Represents the Concentration of the Sulfide.]h^+] Represents Hydrogen Concentration in the Environment.]h_{2s}] Shows the Concentration ofh_{2s}.(k) is equilibriums Constant, and its Rate at the Temperature of 250 is: k= 9/12×10−8

$$pH = -Log|H^+| \quad (4)$$

$$R = 8.3144 j/mole/k \quad و \quad Ln\left[\frac{k(T)}{k(To)}\right] = \frac{\Delta H}{R}\left[\frac{1}{To} - \frac{1}{T}\right]$$

Where ® is Gas Constant. (to) = Temperature of 25c. K(to) is Also Related to This Temperature.

$$\Delta H = \Delta H\overline{S} - \Delta H_2S = -1603 + 3806 = 22.3(kg/mole)$$

After Describing Chemical Equations of h_{2s} Production, Mathematical Models Associated With the Issue Were Investigated in Which 5 Models Were Better other Models, Including:

$$r_a = 0.5.10^{-3} u(C_{BOD_{Total}})^{0.8}.(C_{so_4^{-2}})^{0.4}.1.139^{(T-20)} \quad (6)$$

$$r_a = 0.228.10^{-3} C_{BOD_{Total}}.1.07^{(T-20)} \quad (7)$$

$$r_a = 1.10^{-3} C_{BOD_{Total}}.1.07^{(T-20)} \quad (8)$$

$$r_a = k.10^{-3}(C_{COD} - 50)^{0.5}.1.07^{(T-20)} \quad (9)$$

In These Investigations, There is a More Effective and Comprehensive Including an Effect of Hydraulic and qualitative Parameters of The Wastewater. Relationship Between Parameters is Given in The Form of a Relations Called (Z) Which is Described as Follows:

$$Z = \frac{3.BOD_5.1.07^{(T-20)}}{\sqrt{S.Q}}.\frac{P}{b} \quad (10)$$

It`s Parameters are Defined as Follows:

BOD: Biological Oxygen Demand After Five Days. (B): Width of Flow Level. (T): Temperature (”c°”). (Q): Discharge of Wastewater Rate m^3/s.(p): internal wet Environment (”m”). (s):Slope of Sewer," dimensionless". Described Formula is a Model Based on Which we Can Tell How Much is h_{2s} Rate in Wastewater Network and Which Classification of h_{2s} Measure Ments This Amount Belongs to, and Which Expression is Risk Chance. However (Z) is a Formula That its Value is Relevent to Changes in Hydraulic Parameters in Wastewater, and Based on Which we can Guess and obtain Proper Design Parameters. Large Biological Loads Cause too Much Increase in h_{2s} Production Which Results in Exacerbated Corrosion. reduction in Section of the Network is Effective in Gas Production. Reduction in Setting Slope of Pipes is an effective Factor in Gas Production.Temperature and Biological Constant are Very effective. So all Designs Should be Prepared By Hydraulic Parameters and put into Described Relations in Order to Check Out the Cause of Destruction and Corrosion in Networks; Namely, h_{2s}. However, the best Relation is Relation(10). Thus we Can tell Which Class of The Gas Production Each Pipe in Collection Network Belongs to. In Addition, We Can See That there are 4 Classifications For h_{2s} Production.

Table (1): Rate And Like LaHood of h_{2s} Production According to Formula(Z)

Lower Limit	Parameter	Upper Limit	Risk Assessment
0	Z	5000	Does Not Exist
5000		10000	Likelihood ofh_{2s} Production
10000		25000	High Likelihood of h_{2s} Production
25000			Dangerous, High h_{2s} Production

Discussion and Conclusion: Investigations Determined That Quantitative

And Qualitative Parameters have Significant Impact on h_{2^s} Production. All Mathematical Relations Described are Effective in Determining Rate in Wastewater Collection Networks.

Problems: That May Arise Due to High Sulfide Production Include Production of Poisonous Odors Which Put People`s Health in Danger, Corrosion of Cement and Metals Used in Networks Construction, and Blocking Wastewater Treatment Process in Networks. This Means Inconsistency With Sustainable Environmental Developments in all Aspects. In Relations 6, 7, 8, and 9 We Can See That h_{2^s} Production Rate is Dependent on Qualitative Parameters of the Wastewater. Barely (BOD ORCOD) Has a Significant Role in This Relations, That Should be Always Calculated for Estimating h_{2^s} Rate. Mathematical Model (8) Has Biological Factor (K) Whose Value Depend on type of Wastewater (urban and Industrial Wastewater 6,7,8, are More Efficient For Wastewater Collection Pressure Pipes. In This Study, Mathematical Relation (Z) Having all Quantitative and Qualitative Parameters, Was Evaluated Highly. Wastewater Collection Networks are Designed Half_ full; There Fore, We Should Consider Best Ratios of H/D (Height of Wastewater to the Diameter of Pipe) q/Q_{full} ‘ v/V_{full} ‘ a/A_{full} ‘ p/P_{full} at The Entire Design Time. The effects of h_{2^s} Production Rate on Individuals` Health and Health Issues Were Also Studied. The Results are Given in Table (2).

Table (2): Production Rate Along With Individuals` Reactions

h_{2^s} rate in the Surrounding air "PPm"	Individuals` Reactions
< 0/13	odorless
1	With Slight Odor
5	With Clear Odor
10	Health Limitations to Work During the Day
10-50	Limited eye irritation and Discomfort
30	With Very Unpleasant Odor
50-100	Minor Problems to Senses of Sight and Smell, and to Breathing Just in one Hour Contact time
100-1000	Unconsciousness and Death

Suggestions:

1 Designing Urban and Industrial Wastewater Collection Networks Should not be Based on Hydraulic Relations, Rather Best Designing Should be Based on Quantitative and Qualitative Parameters. 2_ as we saw, qualitative Parameters are Very effective in h_{2^s} production; There fore, in Order to decrease h_{2^s} production, Industrial Waste Must Be Prevented From Entering Urban Wastewater Collection networks Directly. 3_ in Order to Avoid Wasting Enormous Financial Costs(Maintenance and Replacement) Affected By Corrosion in Pipes, Model (Z) Must Be Included While Designing For Best Design. 4_Continuous Good Monitoring During Implementation of Networks is Mandatory. 5_Considering the Impact of Temperature Factor in Accelerating Biological Reactions, it Should be Pursued More Seriously in Cities With Warm Climates. 6_ Using Model (Z), We Can Determine Best_ Type Networks in Terms of Material and Coatings Against Corrosion.7_ Economical Issues Caused By Changes in Networks Design Should Be Studied. 8_ By Including The Unpleasant Odor is Produced By Wastewater. 9_ Most Iranian Cities Do Not Have Wastewater Treatment Plants, so The Wastewater Produced, Directly Enters Aquatic Ecosystems. If h_{2^s} Rate is Higher than allowed Limit, There is a Possibility Of Toxicity to Aquatic Organisms, so it is Necessary To Include These relations.

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