IJSRM
INTERNATIONAL JOURNAL OF SCIENCE AND RESEARCH METHODOLOGY
An Official Publication of Human Journals

Human Journals
Research Article
November 2016 Vol.:5, Issue:1

Simple Technique for Gases Dispersion at WWTP Inlet

IJSRM
INTERNATIONAL JOURNAL OF SCIENCE AND RESEARCH METHODOLOGY
An Official Publication of Human Journals

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Submission: 10 November 2016
Accepted: 15 November 2016
Published: 25 November 2016

HUMAN JOURNALS

www.ijsrm.humanjournals.com

Keywords: Wastewater works, odor control problem, removal of odor problem, air dispersion and activated carbon application

ABSTRACT

A new concept for odor control concentrates on the use of the air temperature and heat transfer of the gasses to remove the bad smell of odorous gasses especially H_2S gas at the entrance of the sewage treatment plant. A new design had been applied using solar chimney conical shape erected above the inlet manhole to increase the gases suction that may be dispersed in the higher layer of the air increasing the area of its dispersion that diluted its concentration in the surrounding air to the permissible limit or treated by activated carbon at chimney top that adsorb it and remove from air that achieved air with only traces of H_2S gas in it. The experimental field work was held on the headwork building in El Riqqa waste water treatment plant in Kuwait during the study period. The solar chimney had been applied with three different sizes for the outlet top to obtain the optimal sizing for the chimney related to the inlet diameter and its height. The experimental work made without activated carbon application in first round then the activated carbon applied in the second run. The study had concluded that the application of the applied solar chimney had succeeded in decreasing the H_2S gas concentration in the surrounding air by 30-40 % and inside the headwork by 50-60% for the screen room and from 70-80 % for the grit removal chamber that ease the work inside the headwork building to the labors and improve the environment with almost minimum cost. The application of activated carbon at the chimney top removed all the H_2S gas from the effluent of the chimney and help in decreasing the H_2S gas in the head works area by 70% at screen and 90% at grit removal chamber which make them inside the permissible limits for air content of such places.

INTRODUCTION

One of main environmental problems is the atmosphere pollution causes by the appearance of high amount of few gasses emitted by WWTP disposal facilities in the State of Kuwait. Air observation has been arranged to calculate attentiveness stage of gasses let out by municipal sewer water treatment plant, an industrial sewer water treatment plant founded in a petroleum refinery, and at a landfill site used for removal of solid wastes.

Additionally: there are many various technologies odor on the view of Kuwait that can be applied to control odors from sewer water collection and treatment method. These technologies can be classified into two main parts: vapor-phase technologies, used to maintain odorous compounds in the air or gas; (i.e. wet chemical scrubbing system and dry carbon adsorption system) and liquid-phase technologies, used to maintain odorous compounds in the liquid wastewater itself (i.e. inject chemical/biological products, Sodium Hypochlorite). Vapor-phase technologies typically are used in point-source applications such as sewer water treatment plants and pump stations. Liquid-phase technologies characteristically are used in collecting systems where maintains of both odors and corrosion are concerned and/or where numerous point odor control is an objective **[1]**.

Hydrogen sulfide is generated within sewage when sulfates, naturally present in wastewater, are converted to hydrogen sulfide by bacteria residing in the slime layer on the pipe walls, or on debris in the wastewater. This activity increases when certain conditions exist in the collection system such as low dissolved oxygen content, high strength wastewater, long detention times, and elevated wastewater temperatures **[2].**

According to Edwards *et al.'s* **[3]** Hydrogen sulfide is the most commonly known and prevalent odorous gas associated with domestic wastewater collection and treatment systems. It has a characteristic rotten egg odor, is extremely toxic, and is corrosive to metals such as iron, zinc, copper, lead and cadmium. Hydrogen sulfide is also a precursor to sulfuric acid formation, which corrodes lead-based paint, concrete, metals and other materials. Zhang *et al.* [**4**] reported hydrogen sulfide emission in sewer systems is associated with several problems, including biogenic corrosion of concrete, release of obnoxious odors to the urban atmosphere and toxicity of sulfide gas to sewer workers. Most odor problems occur in the collection system, in primary treatment process and in solids handling facilities. Therefore, to minimize nuisances and mitigate corrosion problems, collection and treatment of emissions containing H_2S in wastewater treatment plants is essential.

The most common community health complaints resulting from exposure to odor-producing chemicals are:

- Respiratory (breathing)

- Upper respiratory (eye irritation, scratchy throat)
- Lower respiratory (coughing, wheezing)

- **Gastro-Intestinal** (stomach) (vomiting, diarrhea)

- Central Nervous System (CNS) (drowsiness, dizziness, headaches)

- Cardiovascular (heart) (tachycardia (increased heart rate), increased blood pressure)

- Psychological (mood changes, behavioral changes)

Usually, these symptoms occur at the time of exposure and end within a short time after the odor disappears. Although this situation is highly undesirable, the health effects usually end when the exposure to the odor ends and rarely requires medical attention.

Marisel **[4]** indicates the determination of odor source strength is the first step in solving an odor problem, but unfortunately, odors are difficult to measure. Basically, two classes of odor measurement are frequently used: analytical and sensory measurements.

There are two approaches to measuring odors first is by observe and record the odor sensation or reactions, and the second is by capture and measure the chemical compounds stimulating the odors. The human-based approach, known as olfactometry, is more common. The most common odor parameter determined during odor testing is “odor concentration” (odor strength). This determination is made using an instrument called an “olfactometer” done by Charles M. *et al.* **[5].**

There are many different technologies which can be applied to control odors from wastewater collection and treatment systems. These technologies can be split into two main groups:

1. Vapor phase technologies

It is used to control odorous compounds in the air or gas. Vapor-phase technologies typically are used in point-source applications such as wastewater treatment plants and pump stations (wet wells, headwork, etc.) or for the treatment of biogas. The technologies used in treating the ventilation air or biogases are wet air scrubbing, liquid redox technology, biofiltration, solid scavengers and carbon adsorption.

2. Liquid phase technologies

It is used to control odorous compounds in the liquid wastewater itself. Liquid-phase technologies typically are used in collection systems where control of both odors and corrosion are concerns and/or where multiple point odor control is objective. The liquid-phase technologies are iron salts, bioxide process, oxidizers and anthraquinone done by Harshman and Barnette **[6].**

Research done by Shareefdeen **[7]** in all-purpose classification of common technologies applied for VOC, H_2S and odor control is presented in Figure1. This classification is based on the nature of each control technology, that is, physical, chemical or biological. Generally, physical processes are mostly applied for gas streams where the flow and pollutant concentration are high. Important parameters for a proper application of a biological treatment are the solubility and the biodegradability of the compounds to be removed. The most important advantage of biological treatment methods over physical and chemical technologies is the fact that biological processes can be operated at local temperature and pressure.

However, to make a good selection of a treatment method, flow rate, type of pollutant and its concentration must be considered. Other important factors that determine the selection are temperature, oxygen content of the waste gas, stream composition, solubility, production time pattern, and investment and maintenance requirements. The occurrence of secondary environmental impacts and pollution transfer must be evaluated too **[7].**

According to Corey **[8],** there are a wide variety of odor control products available on the market today. The majority can be grouped into three distinct categories:

1. Adsorption (Activated carbon and other adsorptive medias)

2. Biological Oxidation (bio-filtration and bio-scrubbing)
3. Chemical Scrubbing (acid and caustic wet scrubbing)
4. Each technology has strengths and weaknesses:

a. General description of the technology and how it works for odor control.

b. Odors most effectively and least effectively treated and removal efficiencies.

c. Airflow capacities.

d. Capital and operating costs.

e. Operation and maintenance considerations (e.g. frequency of downtime, ease of servicing, utility requirements, footprint and overhead clearance requirements).

f. A general idea of when to and not to apply the technology

Ventilation is one of the simplest methods for odor control. It is progression of supplying fresh air to an enclosed space and removing from it air contaminated by odors, gasses, or smoke. Air movement in a building is caused by pressure differences that occur due to a combination of wind pressure, thermal buoyancy, and mechanical ventilation [**9**].

Natural ventilation is the process of supplying and removing air through an indoor space by natural means. There are two types of natural ventilation occurring in buildings: wind driven ventilation and stack ventilation [**9**]. Bhat *et al.* **[10]** said in natural ventilation the fresh air is introduced without using any external energy source or mechanical machines but only by judicious selection of site, orientation of building and locations of openings.

Natural stack ventilation uses the chimney effect: high and low pressure zones created by rising heat air, causing convection currents: the warmer indoor air rises up through the house till the attic or another top part of the building; this rising warm air reduces the pressure in the base of the house rooms, allowing cold air to infiltrate through strategically placed open spaces (windows or other openings) **[11].** With the increasing needs of ventilation systems in building which are efficient and in harmony with nature, solar chimney is increasingly used in passive solar houses or hybrid ventilation systems **[12].**

A solar chimney is one of the several available options for achieving natural ventilation in building through solar-induced air movement of air. Solar energy heats up the air inside the chimney. As a result of the temperature difference in air, a density gradient between the inside and outside of the chimney is obtained that in turn induces a natural upwards movement of air **[13] & [14].**

MATERIALS AND METHODS

Riqqa Wastewater Treatment Plant (figure (1)) consisted from three treatment stages using activated sludge system for secondary treatment to treat up to 180000 m^3/day of wastewater.

Now, Riqqa plant is considered to be one of the most advanced and efficient treatment plants in Kuwait producing high-quality water, according to international standards, that is currently used for irrigation in forestry and landscaping projects.

One of main, problems in wastewater treatment plant is the emission of unpleasant gasses accompanies raw sewage. H_2S is regenerated in the underground pipes connecting pump station and WWTP. Henley, the main objective of the current study is to assess the reproduction of H_2S gas after the pumping station (near Riqqa WWTP) and try to reduce its concentration in the inflow chamber manhole before entering the WWTP headworks.

The inflow chamber manhole considered near from the building of primary treatment (Headwork's Building) as shown in figure (2).

Most of the gasses especially H_2S are removed before the primary stage in the pumping station. Hydrogen sulfide is generated due to anaerobic microbial activities in sewer system. The sulfide produced is released in gaseous form, leading to health threat to workers at the sewage facility and economical threat due to corrosion of concrete and steel structure in the sewer and associated systems. Hence controlling this phenomenon became inevitable.

Figure (1) Riqqa Plant

Figure (2) Photo Headwork's Building

Inflow chamber manhole of Riqqa WWTP was chosen to be to assess hazardous gasses concentration. Hazardous gasses such as H_2S, CO_2, NO_3, CH_4, NH_3 and NO are normally emitted during the primary treatment stage, which can harm the workers nearby who are exposed to the gasses continuously. Especially, during summer seasons due to high ambient temperature that persists for about 6+ months per year, where temperature could reach as high as 54ºC. This enhances the activity of anaerobic bacteria and hence increases the emission of harmful odors.

Also, long retention time, due to low sewage flow rate in the underground pipe from A15 pump station increases reproduced of H_2S. Hence, reducing the concentration level of these gasses in the air layer above the wastewater level and emitting them away from the workers will reduce the risk of getting infected and will be of interest to authorities in planning new treatment systems and operational strategies.

The model study is located at southwest the headwork's building in the reqqa treatment plant. The experimental set up consists two parts. The first part is an inflow chamber room. It is 5 m high, 5.8 m wide and 5.2 m long as shown in figure (3).

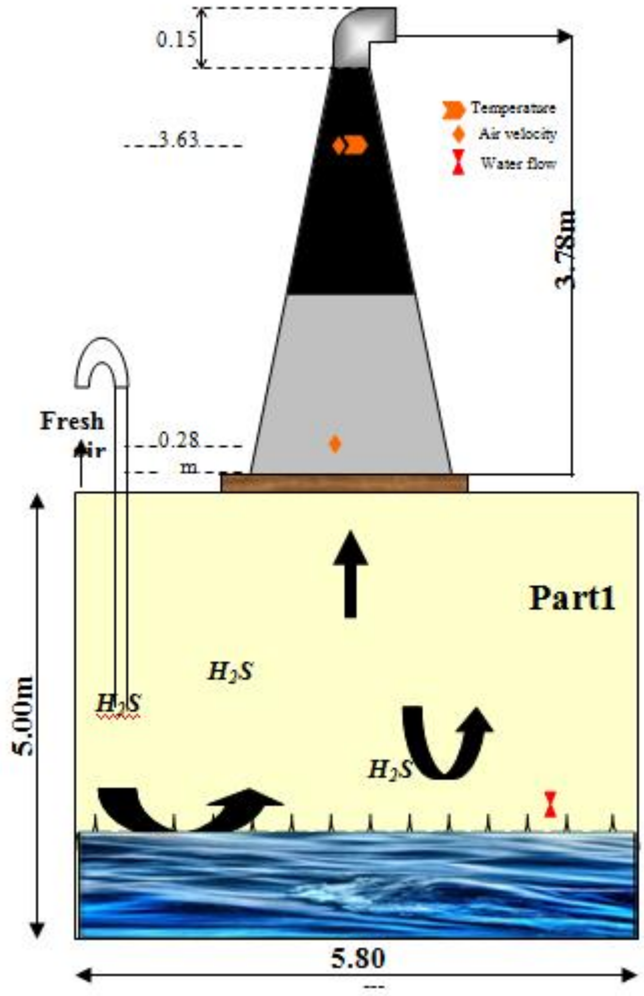

Figure (3) Schematic Diagram of the Experimental Design

The second part is alike solar chimney which consists of two sections a fiberglass at the bottom and the copper at the top. The pilot design has a conical shape and it made from material at base from fiberglass with 1.78 m high, 0.70 m diameter and copper cone diameter is 0.05, 0.1 and 0.17 m at top with 2.00 m high. The copper part coated with black color at the top and in the bottom coated with gray color. The pilot fixed by wood plat has dimension (1.62*1.62 m) which covered on the inflow chamber manhole. The cone copper was painted by black color to exaggerate the internal temperature difference. Therefore air temperature is used to evaluate the performance of the model to remove H_2S gasses from inflow chamber manhole. For choose height of model from literature review **[13]** said “the temperature difference causes the difference in density which results in the pressure difference between the indoor air and outdoor air. And to cancel wind effect, the pilot height was designed smaller than headwork building and it was covered by wind-driven protection as shown in figure (4).

The operating study had been taken from March to August 2014; it was daily at 06-12 AM. The study analysis was divided into two parts, air and water measurements.

The air measurements were for the concentration of H_2S, temperature and flow air in five locations for the study unit. Typical Chemical Analysis for sewage entering the plant, specifically in the manhole before headwork's building had been made. Also, measuring the speed of sewage flow in it was done to get all the required data for the control parameters of the design model of the study. The time period of sampling was divided due to device erection in the site. From **02/03/2014 to 31/05/2014** the daily sampling was taken before the erection of the solar chimney device. And period from **03/06/2014 to 04/04/2014** the daily sampling were taken after the erection of the solar chimney device.

Also, the period from **05/08/2014 to 23/08/2014** daily samplings were be taken with the installation of activated carbon in the solar chimney device. Before the erection of the solar chimney device using multi-gas detector and thermometers to calculate gas concentration of H_2S and temperature. After the erection of the solar chimney device using a data HOBO U12 system with external sensors to measure outlet air temperature, outside temperature and flow rate air measurements.

RESULTS AND DISCUSSION

Three sets of data that depict variation of H_2S concentration from **02/03/2009 to 31/05/2009** before device erection and from **03/06/2009 to 04/08/2009** the daily samplings were taken after the erection of the solar chimney device. Also, the period from **05/08/2009 to 23/08/2009** daily samplings were taken with the installation of activated carbon in the solar chimney device. All of the results are plotted in Figures. (5), (6), (7), (8), (9) & (10). Data collected from outside, inflow chamber and headwork’s building (measured by station operators) by (**Gas Alert Max XT**) device of measurement.

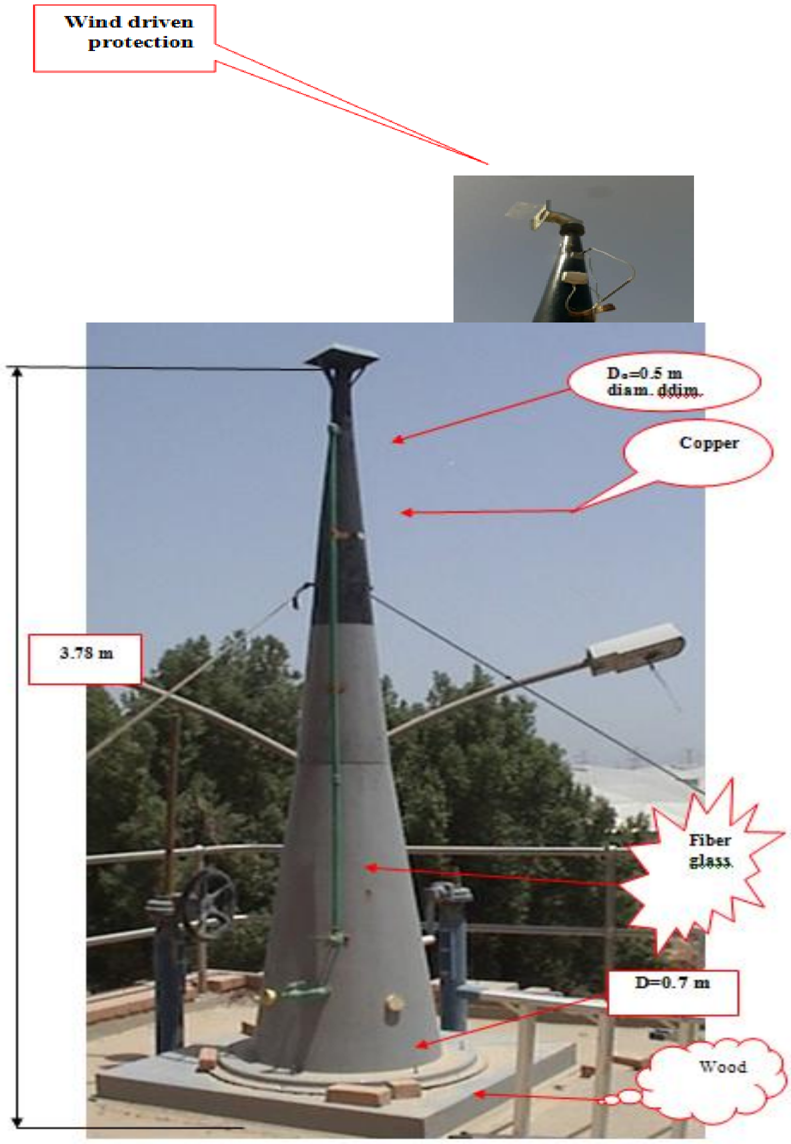

Figure (4) Photo Pilot Design

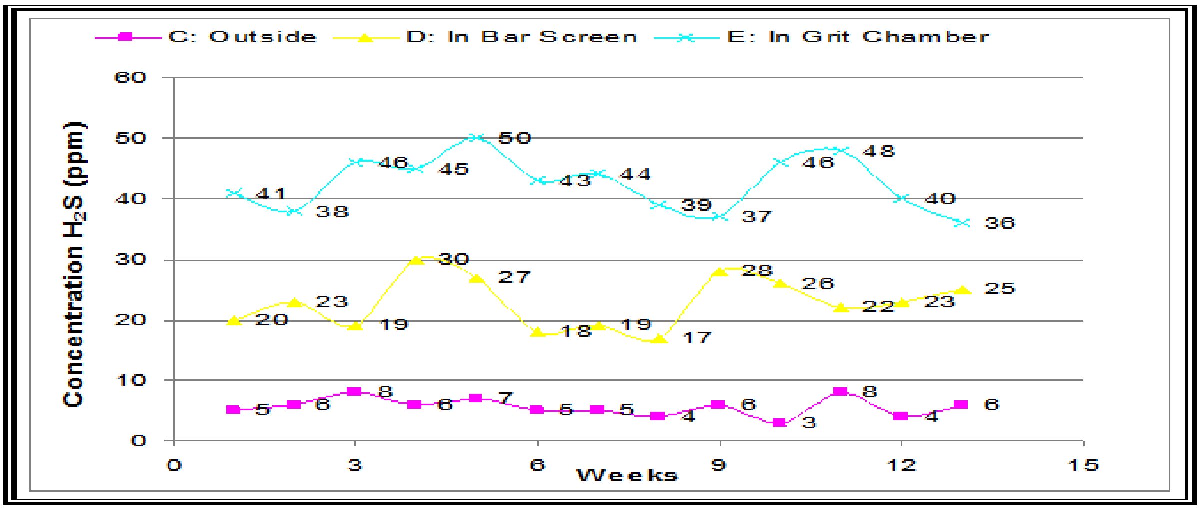

Figure (5) Average (H_2S) at Period before Device Erection

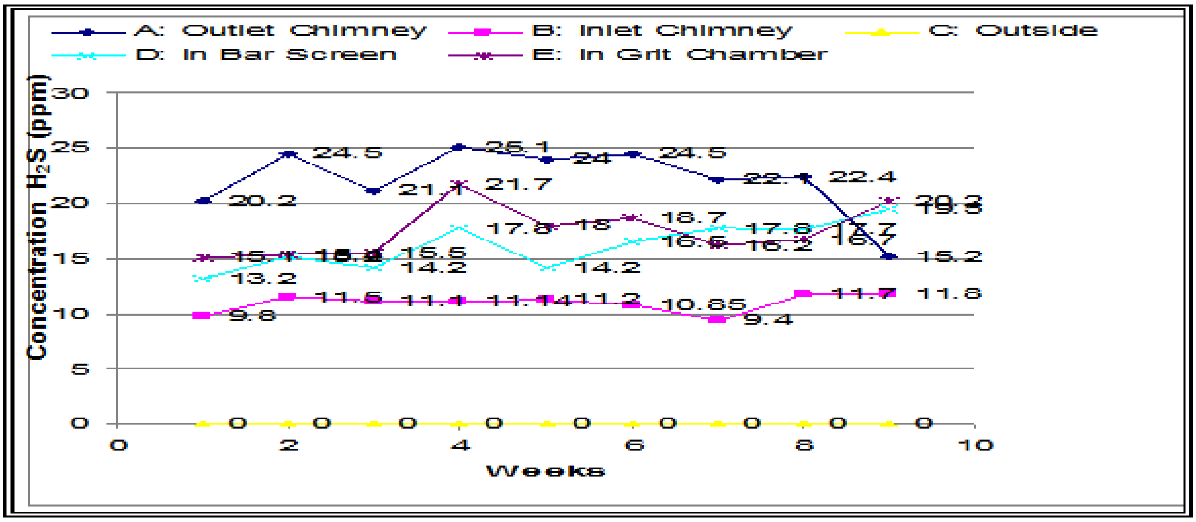

Figure (6) Average (H_2S) at Period after Device Erection

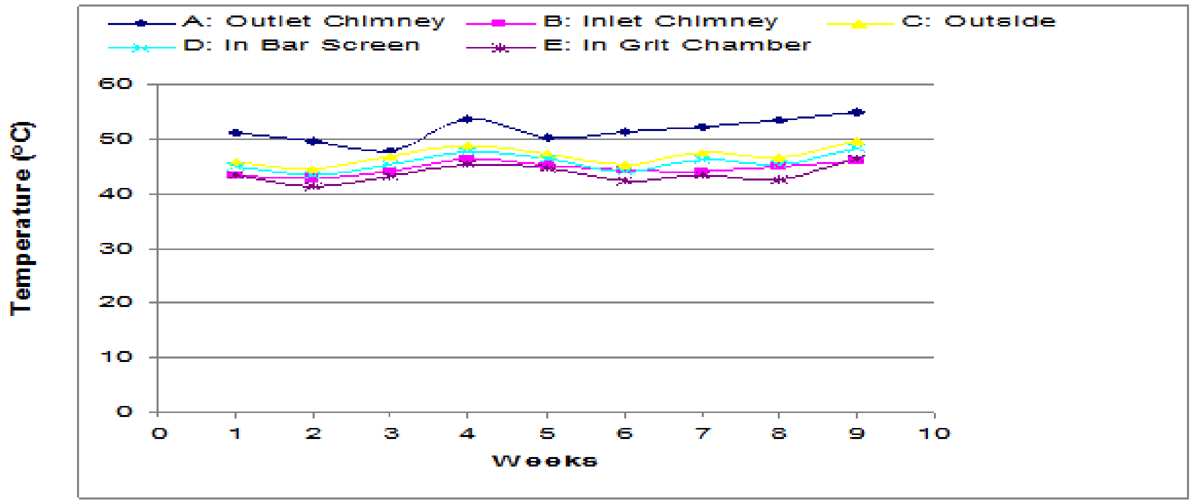

Figure (7) Average Temperature at Period after Device Erection

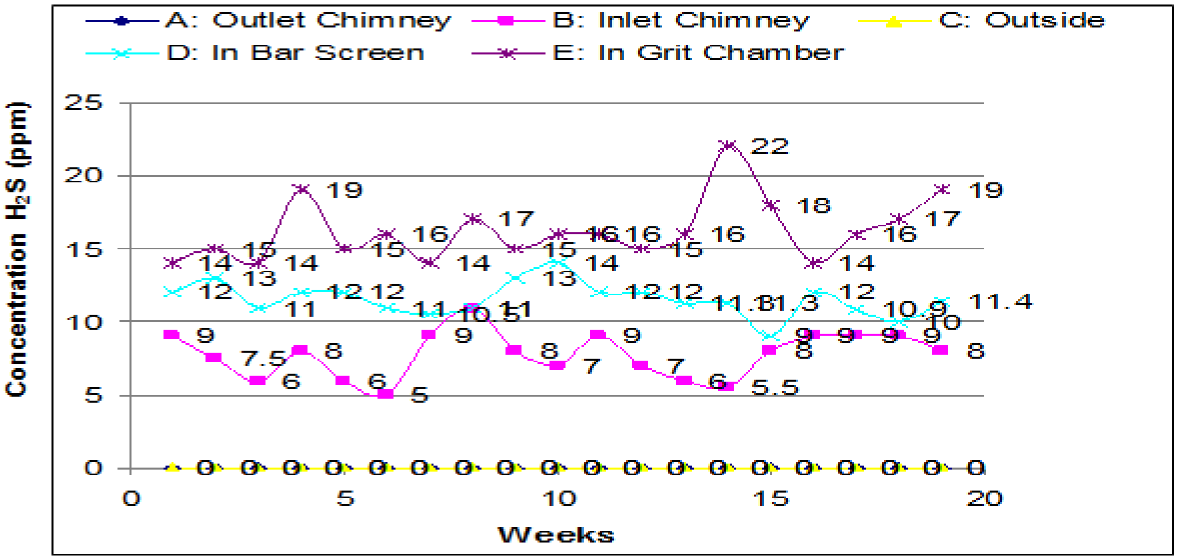

Figure (8) Average (H_2S) With Activated Carbon in Device Erection

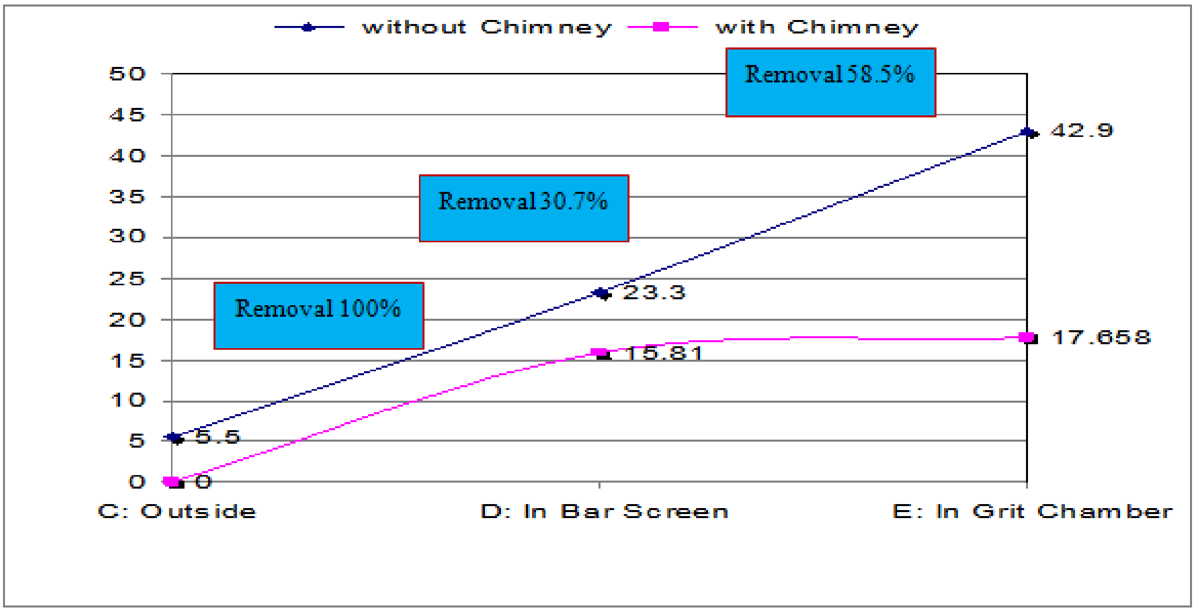

Figure (9) Concentration of H_2S before & after Device Erection

Figure (5) shows that the highest H_2S inlet concentration was 60 ppm recorded in grit chamber, 30 ppm in bar screen and 8 ppm in outside. This shows clearly that H_2S has been reproduced in the underground pipes connecting pump station and wastewater plant. This indicates that pump station treats only gaseous fraction of H_2S and hence dissolved sulfur in wastewater was left untreated, which is converted into H_2S gas in the underground pipes leading to wastewater plant. Also, this shows that temperature has a significant effect on anaerobic bacteria activities that converts sulfur to H_2S. It is apparent that H_2S production increases with temperature.

Figure (6) shows that H_2S inlet concentration was detected in five locations (A,B,C,D,E) after device erection and it can be seen that H_2S outlet chimney is higher than either sample locations this mean the device was operated and released high concentration H_2S from inflow chamber manhole to outside before entering to headwork building.

The highest H_2S inlet concentration was 25.1 ppm recorded in outlet chimney, 21.7 ppm in grit chamber, 17.8 ppm in bar screen, 11.8 ppm in inlet chimney, and 0.0 ppm in outside which it was good result. The device did not detect any value for H_2S in outside location near from chimney model.

Figure (7) shows that air temperature inlet degree was measured in five locations (A, B, C, D, and E) after device erection. Data measured by **(TMC6-HC)** sensor to measure outside temperature and inlet and outlet air temperature in solar chimney and by using (**SDT8**) device of measurement to measure air temperature in the bar screen and the grit chamber in the headwork building by station operators. We noted the air temperature at outlet chimney always was higher than other location because of a copper coated with black color at the very top of the chimney. In the natural circulation tower, the gas temperature inside the copper (any good conductor) tube located at the top of the tower will be elevated by sun radiation.

The highest air temperature was 53.8°C recorded in outlet chimney and the lowest one was in grit chamber and equal to 41.1°C. Figure (7) shows that air temperature increases throughout the year from winter to summer until it reaches a maximum value around June and decreases as the weather shifts back to winter.

Figure (8) shows that H_2S inlet concentration was detected in five locations (A,B,C,D,E) after installation of activated carbon in the solar chimney device to protection environmental form H_2S significant damages and destruction to concrete and steel structures in the sewer or associated systems. And it can be seen that H_2S concentration at outlet chimney and outside is zero and percentage H_2S was less in either sample locations. This means the device was released odorous gasses from the atmosphere this is the great concern from study.

Finally, these results encourage research to develop the solar chimney to be used in the environmental protection in tropical conditions as shown figure (9). It shows that H_2S inlet concentration percentage was lower always higher than either point.

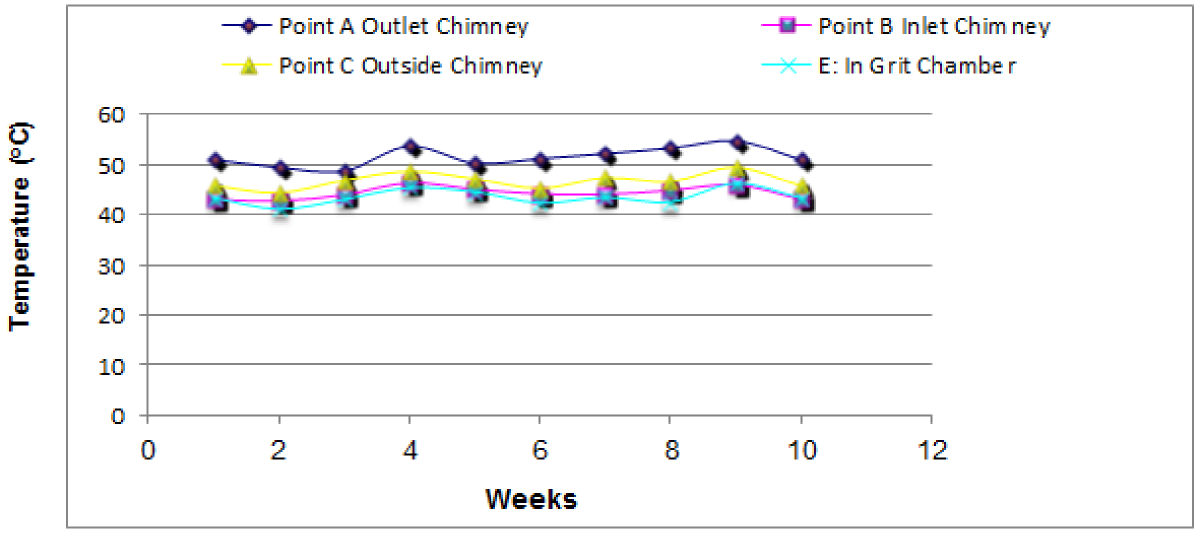

Figure (10) Temperature in Different Positions with Device Erection

Temperature measurements illustrated in figure (10) shows that air outlet temperature is.

CONCLUSIONS

The study results had concluded the following:

1. The application of the solar chimney that use a metal part to increase the temperature inside the upper part of it to help in gas rising to the chimney had succeeded in decreasing the H_2S gas concentration in the surrounding air by 30 -40 % and inside the headwork by 50-60 % for the screen room and from 70-80 % for the grit removal chamber that ease the work inside the headwork building to the labors and improve the environment with almost minimum cost.

2. The application of several sizing for the chimney top outlet shows that the optimal size was between 10 to 15 cm depending on the height of the chimney and the inlet diameter of it.

3. The application of activated carbon as adsorbent material at the chimney top before outlet removed all the H_2S gas from the effluent of the chimney and help in decreasing the H_2S gas in the head works area by 70 % at screen and 90 % at grit removal chamber which make them inside the permissible limits for air content of such places.

4. The system could be applied for the open areas as wastewater treatment plants without activated carbon use with good results. But for the applications with the sewage pump stations that lies inside the inhabited areas the need for activated carbon application is essential. In both cases, the system is a very good and cheap solution for such odor problem in hot climate countries.

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