Part -1 (Environmental Science)
Chapter-I
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Municipal Wastewater Treatment Plants Monitoring and Evaluation: Case study Dammam Metropolitan Area

Abstract: In this study Sewage Treatment Operation and Analysis Over Time software (STOAT) was applied to evaluate, check and improve municipal wastewater treatment plants (WWTP's) in Dhahran city (North Sewage Plant NSTP) and (Dammam Sewage Plant DSTP) in Dammam city. This was done taking into account previous researches, which tackled WWTP's in the Kingdom of Saudi Arabia (KSA) and other Gulf countries. The accomplished work covered a detailed explanation of significant factors influencing wastewater treatment process, operation and performance. Two detailed questionnaires were designed, first one for data collection and assessment of existing WWTP to apply the information in STOAT software to evaluate and improve performance of the WWTPs, while the other for assessment of general public opinion about treatment aspects. Results acquired from the STOAT software in this research showed its usefulness and convenience. From results, minor differences are noticed between NSTP and DSTP. Running STOAT for both plants indicated significant change in treatment process. Thus, pointing to erratic behavior in operation. The software showed no effects on sludge treatment. Generally, STOAT software results compared well in reality with an error of 15%. It was concluded that STOAT software is very good for analysis and performance evaluation of WWTP and for research or further studies in this regard. Recommendations for further improvement of WWTP's are suggested.

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Background

Wastewater treatment refers to process of removing pollutants and contaminants from water previously employed for industrial, agricultural, or municipal use. The objective of wastewater treatment plant is to produce an environmentally safe fluid waste stream (or treated effluent) and a solid waste (or treated sludge) suitable for disposal or reuse (usually as farm fertilizer and soil conditioner). Using advanced technology it is now possible to re-use sewage effluent for drinking water (Sandiego, 2013), or at least for irrigation if advanced technology is not applied.

This research project is aimed at evaluating design, operation, performance, efficiency and management of an existing wastewater treatment plant and associated processes. The main objective is to assess best ways of developing sustainable wastewater treatment plants that are used in areas of the Eastern Region of KSA focusing on technical aspects of an existing wastewater treatment plant design and performance using STOAT software (WRC, 2006). Specific research objectives and expected outcomes included the following:

- Assessing current status and operation of existing wastewater treatment plant.
- Checking effectiveness of design of different unit operations and technical performance of existing treatment plant using STOAT.
- Inspecting accomplishment effluent standards in terms of different pollution loads.

Research hypothesis assumes that by using STOAT for monitoring an existing wastewater treatment plant, there will be improvement in its performance and operation.

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Scope and motivation of the project views that wastewater production is increasing as more utilities are connected to the sewerage system in Dammam-Khobar area. Evaluation of design parameters and treatment plant performance is a necessity to improve the facility and augment removal efficiencies. Case study design principles in the design of wastewater treatment works (WWTW) in cities of Dammam or Khobar constitute the bulk aspects of this research work. Investigation would consider evaluation of environmental issues besides assessment of functionality wastewater treatment plant units. STOAT software would be utilized in performance and design analysis. As a case study, different combinations of controllers would be implemented, simulated and evaluated (Al-Shahwan, et al, 2014).

Classification of sources and characterization of properties of wastewater necessitates data collection through a survey of a selected wastewater treatment facility. Analysis of data would be conducted through a chosen model and program unit operations to lead to appropriate sustainable design and operation. Literature review would constitute a vital component for the work from certain localities (libraries, sites, firms, etc.). Data collection would be through predesigned and set interviews and questionnaires.

Literature review

Global growth of human population and industrial development lead to daily increase of water consumption, with consecutive increase of wastewater and solid waste. Social importance of water management has resulted in legal regulations targeted to optimize the outlet concentrations from wastewater treatment plants (Novak et al, 2013).

Conventional pollutants are degradable with water quality effects and other toxicity characteristics. The focus of municipal wastewater treatment has been the removal of conventional pollutants, particularly 5-day biological oxygen demand (BOD_5) and total suspended solids (TSS). TSS in municipal wastewater streams are primarily organic particles that constitute a major share of the biological oxygen demand within the wastewater stream. Since TSS are in large measure jointly removed with BOD_5 in municipal treatment plants, BOD_5 and TSS represent alternative measures of publicly owned treatment works POTW performance. BOD_5 is used as common measure of conventional pollutant (Fraas, 1984). In order to improve the monitoring, control, and performance of a WWTP, building good predictive models is important both for understanding the dynamics of these highly time varying and complex systems and in the development of optimal control support and management schemes (Honga et al, 2003).

KSA adopted laws, regulation and standards for re-use of wastewater after its treatment to global limits for use in agricultural irrigation, landscape irrigation, recreational places, future groundwater recharge, cooling and industrial purposes (ARAMCO, 1983). In an effort to conserve limited water resources in KSA, a royal decree (M/6-1421H) approved regulations for treated wastewater reuse (Also Published in Um Alqura Newspaper, issue # 3797). According to this policy, reuse of wastewater effluents in irrigation is expected to increase dramatically for next years. Therefore, the health and environmental aspect of these practices is very important (MAW (1989).

Innumerable software is used in designing, assessing and checking operation and performance and treatment of wastewater systems and units. Among these widely used software are: STOAT, SIMTAR, DATAR, EDSS, SIMBA, WEST, and BioWin as summarized in table (1).

Table (1): Summary of some wastewater treatment facilities design, monitoring and operation.

Software	Description	Reference
SIMTAR	A CAD/CAE system. It is a handy tool for design and evaluation of wastewater treatment plants. In this system the whole of stages involved in design of WWTP's (calculation of equipment sizes, cost estimation, and drawing of equipment plants) can be accomplished	Gasso et al, 1992
DATAR	Computer-aided WWTP design system is a tool to facilitate complete WWTP design, biological processes, preliminary, primary, and tertiary wastewater and sludge treatments. The system includes relational database containing information about necessary equipment for wastewater and sludge treatment, as well as elements relative to plant hydraulics. DATAR software evaluates different alternatives and performs sensitivity analysis.	Gabaldon et al, 1998

Continue…

EDSS (Environmental Decision Support System)	Developed to address designing a new wastewater treatment system in rural areas for many variables like alternative connections with pre-existing collection networks or enlarging a pre-existing treatment plant, etc. Alternatives may be evaluated on many aspects such as economical-cost, social (local society opposition to construction of treatment plant or enlarging it) and quality of water streams which treated water will be pumped into. Decision support systems are based on concept of DDM (data, dialog, and model). Thus it helps an engineer or team to arrive at a suitable engineering design	
SIMBA	Allows the user for more comprehensive understanding of the sewer system, WWTP, rivers and sludge treatment. Included in the software are all the components that are needed for detailed analysis and interactions regarding constituent subsystems	Ifak, 2013
BioWin	Investigates biological, chemical, and physical process through simulation and modeling. It is being used to design and enhance WWTP that are already been built and help in the process of building new ones. This biological model is subsidized with other process models like: water chemistry models for calculation of pH, mass transfer models for oxygen modeling. etc.	Envirosim, 2014
STOAT (Sewage Treatment Operation and Analysis over Time)	is a PC based computer modeling tool designed to dynamically simulate the performance of a wastewater treatment works.	WRc, 2006

STOAT software can be used to simulate individual treatment processes or whole treatment works, including sludge treatment processes imports and recycles. The model enables the user to optimize response of works to changes in influent loads, works capacity or process operating conditions. Using STOAT can help to improve effluent quality, reduce risk of consent failures, reduce capital and operational cost, design treatment plants more efficiently, optimize treatment plant operation, troubleshoot operational problems, carry out integrated catchment simulation and train staff in best practice. STOAT contains a range of valuable features that include (WRc, 2006):

- Models all common treatment processes.
- Offers both BOD_5 and COD models.
- New models continually being added.
- Integrates with leading sewerage and river quality models.
- Easy to use, with user friendly interface.
- Includes quick build wizard.
- Support for batch simulations.
- Allows simplified sewer modeling (SIMPOL).
- Easy data transfer to other packages.
- Full telephone/e-mail support (WRc, 2006; Stokes, et al, 2000).

Water Research Centre provided a practical program to customers, operators in water or waste and environmental fields based on simulation of reality through precise calculations and assumptions

(WRcplc, 2006). However, the process is based on insertion of parameters needed to simulate hypothetical wastewater treatment plant performance with reality. The program determines efficiency of plant as evaluated with actual life, chooses best scenarios based on results and works on increasing efficiency of plant processes to highest level with lowest possible cost (WEF, 1998)

Field data collection and methodology

Site inventory evaluation for selected plants began on late September and early October 2013 to gather background data and information that would reveal status of sanitation and wastewater handling in the Khobar-Dammam areas in terms of each of the following (Al-Shahwan, et al 2014):

- Choice of two wastewater treatment plants located in Khobar-Dammam areas. Selected WWTPs were the North Sewage Treatment Plant (NSTP) at Dhahran and Dammam Sewage Treatment Plant (DSTP) (see figure 1).
- Identification of existing types of technologies or systems utilized at elected sites.
- Evaluation of status and level of each existing treatment plant, design capacity, year of construction, and selected location.
- Interviews conducted with personnel, officials, engineers, TP operators and workers at relevant municipalities and councils for these selected wastewater treatment plants.
- Repeated visits to relevant sites and domains.

The research project tried to collect relevant and sufficient data and information for the selected treatment plants (NSTP) and (DSTP) through developing appropriate research questionnaires. In order to make a preliminary study to assess the main issues related to the situation of wastewater treatment plants in KSA Khobar Dammam areas, a questionnaire has been designed. The idea is to gather specific data about each existing wastewater treatment plant that has been selected. The questionnaire is speculated to assist in collecting relevant information towards monitoring of wastewater treatment plants in the study area. Following Arafeh methodology (Arafeh, 2012) the questionnaire is divided into three sections. The first one consists of a number of questions. Some of these questions are of multiple choices, while the remainder requires a short answer. These questions are designed to gather the basic information about the wastewater treatment plant including: source of raw wastewater, current treatment technologies, and operational issues. In addition, this section introduces the technical history for each plant. In the second section, there are three tables that address issues related to main operational and technical problems for each process (primary, secondary and tertiary). The last section identifies the most critical process parameters that may affect efficiency of the wastewater treatment plant. WWTPs questionnaire included basic data of WWTP, information about wastewater treatment processes, control and monitoring systems. It is needed to provide basic information about an existing wastewater treatment plant in the Eastern Region in KSA, in terms of assessing and monitoring plants' process performance. This is in an effort to check performance and attempt appropriate remedial solutions if need be, and to be able to add a technical enhancement for every adopted process if possible (Al-Shahwan, et al 2014).

Figure (1): Dhahran Sewage Treatment Plant, (Google maps, 2013)

North Sewage treatment plant (NSTP) and Dammam Sewage Treatment Plant (DSTP) were chosen as plants that will help the current project and represent similar facilities. This is because these establishments have a new technology that is more informative and is expected to suitably cover research platform and objectives.

<u>Dhahran Sewage Treatment Plant (NSTP)</u>

North Sewage treatment plant (NSTP) is located in Dhahran area. NSTP incorporates an activated sludge wastewater treatment plant, with an average capacity of 14 MGD (53000 m^3/d). Flow enters the plant via gravity sewers from three areas:

- Dana / Doha home ownership areas.
- Saudi Aramco Dhahran areas.
- King Fahd University of Petroleum and Minerals (KFUPM).

Figure (1) indicates the geographical location for the wastewater treatment plant which was selected to be used for evaluation in terms of analytical\operational method.

<u>Dammam Sewage Treatment Plant (DSTP)</u>

DSTP is located in Dammam area, along Dhahran/Jubail highway. The Dammam plant applied an activated sludge wastewater treatment unit, with an average capacity of 85MGD (320000 m^3/d). Like NSTP, flow enters the plant via gravity sewers from east areas of Dammam city.

Figure (2) indicates the geographical location for the second wastewater treatment plant chosen for evaluation purpose in terms of analytical and operational data.

Figure (2) Dammam Sewage Treatment plant aerial view, (Google maps,2013)

<u>Process description for study area</u>

The main purpose of the wastewater treatment plants are water purification to sufficient purity to aid re-use in irrigation and industrial field or to bring it back to the environment without the consequent effects of harms when returned to the sea. Each WWTP contains several processes and stages of purification. Nonetheless, in general, the treatment plant includes preliminary, primary, secondary and tertiary treatment units. Selected WWTP's use almost the same processes with a little difference in these units, as well as a slight difference in the operational parameters in both plants, but with a significant difference in both influent and effluent.

North Sewage Treatment Plant and Dammam Sewage Treatment Plant are activated sludge plants. Both WWTP's use odor control system when the influent reaches plant. This is because both plants are located in populated areas. The head works area consists of mechanically cleaned step screens followed by vortex grit removal chambers. Following the head works, the screened and de-gritted flow is distributed to the aeration tanks where biological stabilization of organic matter is accomplished. The aerated effluent exiting the aeration tanks is conveyed to secondary settling tanks for removal of solids. The secondary effluent from the settling tanks is disinfected and pumped to the advanced wastewater treatment plants (AWTP's) for tertiary treatment by filtration for reuse or disposal to the sea. The advanced wastewater treatment plant (AWTP's) receives treated secondary effluent from (NSTP) and (DSTP), and provides tertiary filtration, disinfection, storage and pumping into the effluent irrigation network as for the NSTP or disposing it to the sea as for DSTP.

Methodology of work

Because of confidentiality of the data, rules and restrictions in these plants, all needed information to be applied in the software to get very accurate results could not be obtained. Several attempts and weeks of data hunting trials, through different official and personal channels, finally relevant information about these stations and necessary needed parameters to run the STOAT software were gathered (as presented in table 2).

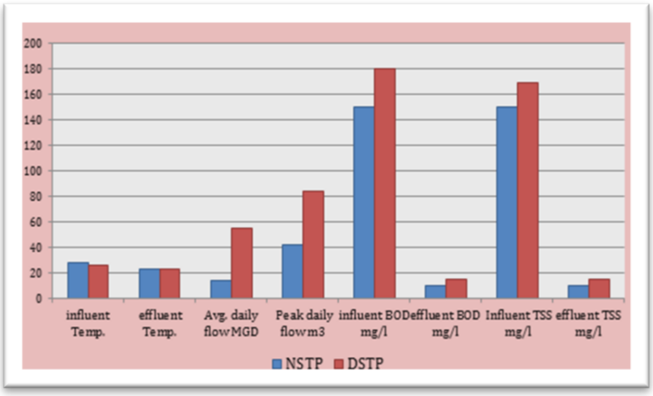
Parameter	Unit	Value of NSTP	Value of DSTP
Average daily flow	MGD m^3/day	14 52,996	55 208,809
Peak daily flow	MGD m^3/day	42 158,990	84 320,000
Peak factor	-	3	-
Influent temperature	°C	28	25
Effluent temperature	°C	23	23
Bar screen spacing	cm	1.8	1.8
Grit trap volume	m^3	30	30
Aeration tank volume	m^3	29841	125600
Number of stages	-	7	8
Secondary sedimentation tank vertical layers	-	8	8
Surface area	m^2	3808	11080
Depth of tank	m	3.6	4 (assumed)
Sand filter volume	m^3	1688	4000 (assumed)
Sand filter area	m^2	800	2600 (assumed)
Chlorination tank volume	m^3	4000 (assumed)	4000 (assumed)

Table 3 and Figure (3) offer a comparison between main operational parameters of NSTP and DSTP

Table (3): Comparison of NSTP and DSTP Operation Parameters

Parameter	Unit	NSTP	DSTP
Influent BOD	mg/l	150	180
Influent TSS	mg/l	150	169
Secondary treated effluent BOD	mg/l	< 15	<20
Secondary treated effluent TS	mg/l	< 15	<20
Tertiary treated effluent BOD	mg/l	< 10	<15
Tertiary treated effluent TSS	mg/l	< 10	<15
Non-volatile solid	mg/l	150	150
Ammonia	mg/l	15	21
Nitrates	mg/l	30	23 (assumed)
Aeration tank DO	mg/l	3	5
MLSS	mg/l	2384 (assumed)	4000
Sludge wastage flow	m^3/h	50	50
Wastage pump run time	h	24	24
Wastage cycle time	h	24	24
Sedimentation Tank DO	mg/l	15	6

Figure (3): comparison between parameters of NSTP and DSTP.

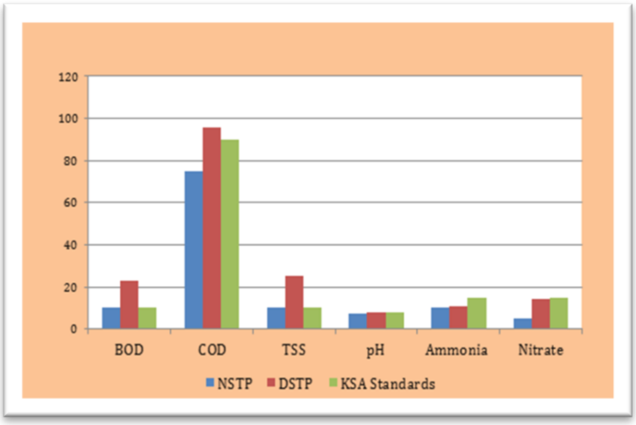


Main parameters of treated water that are used for irrigation in KSA are based on set irrigation standards, as presented in table 4.

Table (4): Effluent Parameters of (NSTP) and (DSTP) as compared to KSA irrigation standards.

Parameter	Unit	DSTP	NSTP	KSA Standards
BOD	mg/l	20 - 25	>10	10
COD	mg/l	96	75	90
TSS	mg/l	25	>10	10
pH	-	8	7.5	6 - 8.5
Ammonia	mg/l	11	10	15

Figure (4) shows a comparison between main parameters of NSTP and DSTP with KSA irrigation standards.

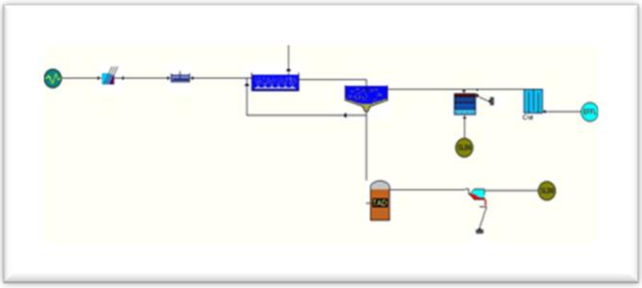


It is noticed from this comparison that NSTP effluent follows KSA standards for irrigation purposes. This is because treated effluent is used in irrigating fields and recreational areas inside Aramco premises. On the other hand, DSTP parameters are higher than set irrigation standards. This could be attributed to DSTP not using treated effluent in any field but follow other standards for disposing it to the sea.

Steps followed for modeling STOAT software were as follows:

6. After starting STOAT software, practical design of NSTP WWTP using existing units and processes toolbox is as shown in figure 5.

Figure 5: Process of NSTP



7. Design parameters are important inputs because it can change process result with time. This will prevent work to run and software will not accept that process. The software demands many parameters that should be known for each unit, such as: volume, area, number of stages, depth of tank MLSS recycle, etc…) as tabulated in Table 5.

Table (5): Design parameters

Edit secondary sedimentation tank : Page 1 of 2

Name:	sedimentation tank
Model:	SSED1
Number of vertical layers:	8
Surface area (m²):	3808
Depth of tank (m):	3.66
Depth of feed (m):	3.66
RAS flow	(•) Rate ( ) Ratio

OK | Cancel | Reset | More | Help

3. Now the software accepts to run the process, and it asks about time required or time needed to show the result or operate the process as in table 6.

Table (6): Running of software

New run (cold start) : Page 1 of 1

Name of run:	NSTP
Start date and time (dd/mm/yy hh:mm):	05/10/2014 00:00
End date and time (dd/mm/yy hh:mm):	05/12/2014 00:00
Input timestep (h):	0.25
Output timestep (h):	1
Average sewage temperature (°C):	15
BOD removed per unit non-biomass VS removed:	0.5
BOD removed per unit biomass removed:	0.5

OK | Cancel | Reset | More | Help

4. After running the process with design parameters, it is time to add the influent parameters upon which all process and all parameters depend. Influent parameters contain BOD, ammonia, temperature, etc. (called generate profile by software) as shown in table 7.

Table (7): Generate profile

Influent pattern [Influent pattern 4]

	Flow (m3/h)	Temperature (deg. C)	Soluble BOD (mg/l)	Particulate BOD (mg/l)	Volatile solids (mg/l)	Non-volatile solids (mg/l)	Ammonia (mg/l)	Nitrates (mg/l)
Mean:	2208.000000	25.000000	150.000000	0.000000	0.000000	150.000000	15.000000	30.000000

5. Initial working conditions and parameters in WWTP for each unit have to be inserted. These parameters are such as: BOD, MLSS, DO, etc. This has to be copied for every stage. In the aeration tank the value of DO for the first stage has to be 0 because the first stage of each aeration tank is anoxic (in absence of oxygen) as presented in table 8.

Table (8): Initial condition for aeration tank

Initial data

		Stage1
1	Soluble BOD (mg/l):	150.00
2	Ammonia (mg/l):	15.00
3	Nitrate (mg/l):	30.00
4	Soluble phosphate (mg/l):	0.00
5	Dissolved oxygen (mg/l):	0.00
6	MLSS (mg/l):	2384.00
7	Viable autotrophs (mg/l):	1.00
8	Non-viable autotrophs (mg/l):	0.00
9	Viable heterotrophs (mg/l):	100.00
10	Non-viable heterotrophs (mg/l):	0.00
11	Particulate BOD (mg/l):	0.00
12	Biomass P (mg/l):	0.00

6. Then the operation condition of the sedimentation tank is introduced for process control and sludge recycled to aeration tank or being sent for sludge units. This is only needed to initial parameters (See table 9).

Table 9: operation data of sedimentation tank

Operation data

		Initial
1	Change at time (h):	0.00
2	RAS flow (m³/h):	2233.00
3	RAS ratio:	1.00
4	Sludge wastage flow (m³/h):	50.00
5	Wastage pump run time (h):	24.00
6	Wastage cycle time (h):	24.00
7	MLSS set-point (mg/l):	0.00

7. It is time to run process in STOAT software and for result to be shown and compared with other results as depicted in table 10.

Table 10: Final running of software

WRc STOAT (version 4.3)

File Edit Options Run Tools Window Help

NSTP Start 05/10/2014 00:00 End 05/12/2014 00:00

8. Results of process can be viewed in many ways: graphical, summary statistics and time seriesformats. Likewise, the software allows viewing result in any unit or any stream that is desired. This will make results easy to compare and also will offer the worker potential correction of mistakes or any wrong values or erroneous results (See figure 6 and table 11).

Figure 6: Graph of effluent results

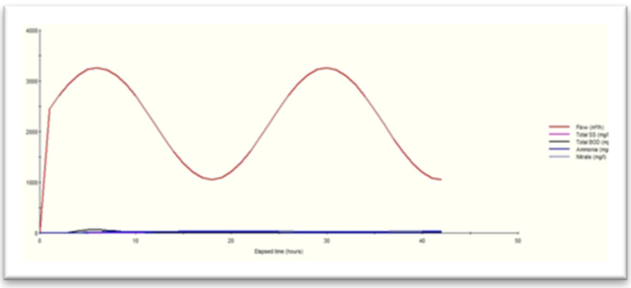


Table (11): Table of statistics results

	Flow (m³/h)	Total SS (mg/l)	Total BOD (mg/l)	Ammonia (mg/l)	Nitrate (mg/l)
Mean	2190.87	3.63	8.28	13.29	31.42
Minimum	0.00	0.00	0.00	0.00	0.00
Maximum	3262.00	6.02	70.44	17.44	39.54
Standard deviation	857.04	1.41	18.24	4.83	11.35
Total mass (kg)		369.287	1090.777	1202.957	2869.766
Peak load (g/s)		4.903	63.823	12.116	30.453

9. Lastly, STOAT allows to change scales of graph and show results in each point.

The work tackled has been reflected into two parts. The first part addressed North Sewage Treatment Plant (NSTP) at AlDhahran area. The second part was allocated for the Dammam Sewage Treatment Plant (DSTP).

STOAT is being applied to a practical case example, for the north sewage treatment plant (NSTP). Data were collected by using a questionnaire that contains a number of questions about the treatment process, design and operation parameters.

After collecting needed data, it was applied on STOAT software to evaluate effluent parameters and results of process operation. This was then compared with performance of Dammam sewage treatment plant (DSTP).

STOAT outstanding characteristics incorporate its user-friendliness, the modular structure, capabilities to define process flow sheet, making of equipment plans and inclusion of range and default values for operational parameters. In running STOAT for Dammam sewage treatment plant the general process did change much. This points to erratic behavior in operation. The situation deserves in depth thought and more investigations to overcome ill effects. Nevertheless, the sludge process is not affected by treatment process. This could be attributed to the huge difference between flows at NSTP and that at DSTP (figure 8). Since the same procedure of running the simulation program is adopted for both treatment plants, only process results will be shown in this part of the research work.

1. The process of DSTP is an activated sludge process, and it contains a thickener in sludge treatment (figure 7).

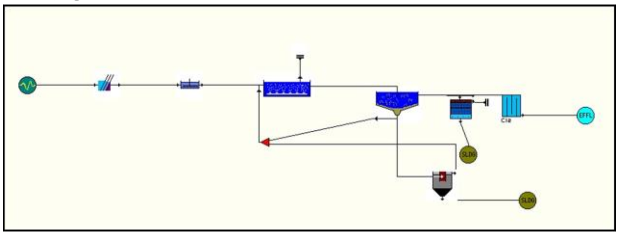


Figure 7: process of DSTP

2. With same procedure of simulation and insertion of design parameters the process is run, insert time required for process, add influent parameters, and add initial conditions for each unit, input operation parameters, run simulation and show results.

3. Results are viewed as a graph or summary statistics data to help comparison of result between WWTPs (figures 8 and table 12).

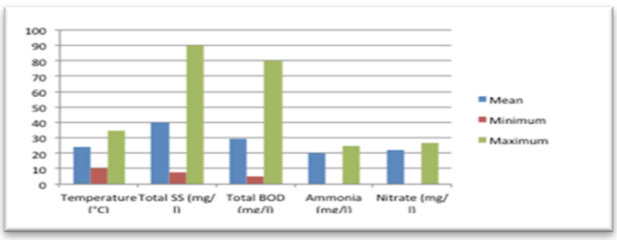


Figure 8: Graph result of DSTP.

Table 12: summary statistics result of DSTP

Parameters	Mean	Minimum	Maximum
Temperature (°C)	24	10	35
Total SS (mg/l)	40	8	90
Total BOD (mg/l)	29.39	4.76	80
Ammonia (mg/l)	20.12	0	24.51
Nitrate (mg/l)	22.37	0	26.87

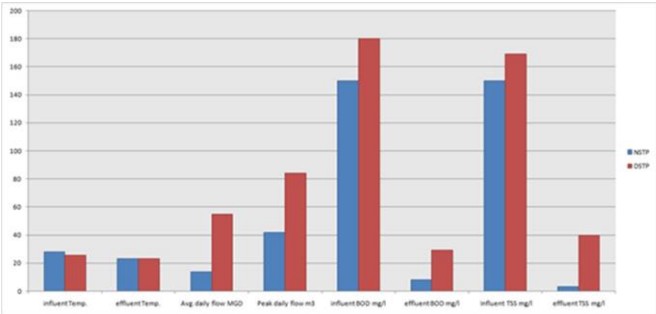


Figure (9) Comparisons between result of NSTP and DSTP on STOAT software.

Small differences were noticed between results from north sewage treatment plant and Dammam sewage treatment plant and software results with an error of 15% (figure 9 and table 12). This refers to software crashing and programing errors, also difficulties were faced due to governmental complex procedure in getting information and data needed for running the software. Eventually, software results are close to reality and will help whoever is concerned about the research or further studies.

STOAT software provided a fruitful way of monitoring processes at the two treatment plants. It offered a platform for an intelligent decision-support system. The results showed that the system illustrated states of activated sludge process and its trends, and therefore it offered a way towards determining a path for more efficient and cleaner wastewater treatment. With the software flexible treatment plant configurations can be established with preliminary, primary, biological and tertiary wastewater and sludge treatment units.

Conclusion and recommendations

The following conclusions emerged from this research work:

1) In running STOAT for DSTP and NSTP the general treatment process did change significantly. This points to erratic behavior in operation. The situation deserves in depth thought and more investigations to overcome any ill effects and droop in efficiency.
2) STOAT showed that the sludge treatment process is not affected for both DSTP and NSTP. This could be attributed to the huge difference between flows and hydraulic loads.
3) Treatment plants design detailing's and operational parameters are essential for operation and monitoring of STOAT software.
4) STOAT system for WWTP's presented in this research work proved to be a useful tool for studying and testing several operational alternatives and performance in rating the two selected facilities.
5) Due to many advantages of STOAT program ought to be applied to all purification plants in KSA as it offers results similar to real working conditions, examines operation of stations and shows deficiencies that need to be studied and developed. There is a great deal of potential using it as a general modeling tool that is suitable for a variety of other complex process systems.

Recommendations for further study

Regardless of the actual amount of effort and time taken to complete this research work, nevertheless, some deficiencies occurred and certain observations were noticed.

1) STOAT program may be improved through addition of some important units such as odor control system, as well as improving operational aspects.
2) Researchers have encountered some problems and obstacles that delayed the accomplishment of the work and hindered its satisfactory compilation. The following suggestions are anticipated to facilitate scientific research, easy future work, improve purification operations at stations and facilitate communication between researchers and plants:
    a. Treatment plants ought to collect needed design and operational parameters and detailed research studies for each unit to stipulate findings and support decision-making.
    b. Researchers need to seek support using actual and realistic design or operational data from other similar stations in case of loss of certain data and information.
    c. Extensive study of surrounding area (in KSA) needs to be carried out. This is through influential factors such as: geographic location, temperature, water availability, population and accessible technology. Thus, aiding selection of optimal and appropriate design for this region based on governing factors.
    d. Creation of a network to enable operators, designers, engineers, and researchers discuss situation of purification plants, ways of development, appropriate methods to increase efficiency, commercial exchange of practical experiences and completion of needs and shortcomings as well as exchange of data and information.
    e. Initiating community education along purification plants and their benefits through distribution of educational and cultural surveys, which helps in reducing consumption and wastage of water.
    f. Maximizing use of treated effluent in agricultural irrigation, groundwater recharge and landscaping issues.

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