

# **Port Wastewater Quality: King Abdul-Aziz Dammam Port Case Study**

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**ABSTRACT:** Marine pollution at ports and harbours incorporates items such as oil, noxious liquid substances, sewage and solid waste of heterogeneous nature. This waste may have ill-impact on aquatic life and hampers the water quality of its surrounding environs. This research project focused on checking water quality as impaired by waste water generated at sea port. King Abdul-Aziz port on Dammam city was chosen as a case study. Objective of the research work is to investigate amount and degree of generated waste and potential remedies thereafter. Wastewater samples were drawn from certain sea localities adjacent to the port for quality investigation. Laboratory investigations and tests revealed absence of pollution and contamination from expected sources at the port..

**KEYWORDS:** Marine pollution. Port water quality. Port wastewater impact.

## **I. INTRODUCTION**

Mohee et al [1] indicated that “industrial port areas introduce many environmental pollution problems including water, wastewater, solid waste, noise and air pollution from municipal, factorial commodities, traffic, marine pollution, industrial cargoes, ship-generated waste, oily spills, solid waste products, underwater stuff, ballast water, storage of hazardous materials, accidents such as fire, leakages and ship accidents, and nuisance odour from chemical substances”.

Ball [2] “concludes in his research that the statutory approach to improving the provision and use of waste facilities should be supported by an appropriate awareness campaign to educate ship-owners about the need to discharge waste legally to port reception facilities”.

Classification of harbor and port wastes in Kingdom of Saudi Arabia (KSA) ought to be dealt with in connection to local and international standards. Appropriate environmental management of such systems is essential to government, municipality and local community institutions. Current legislation and directive sets out to implement hygiene, health safety, and waste prevention and recycling measures need to be revisited [3].

The main objective of the present study is to determine quality indicators with regard to port waste identification in the Eastern region of KSA. The data needed to develop, generate and adopt indicators is to be collected through appropriate samples from different site investigations, laboratory analysis, field visits and well-designed survey studies by suitably designed questionnaires.

This research work investigates current waste and disposal options for waste generated at Dammam Port and the associated impacts of this waste. The work undertaken considers ways of ensuring adequate provision of reception facilities, and discusses the approach taken by authorities to reduce the amount of pollution entering the marine environment from the deliberate discharge of waste from ships. An important measure adopted by concerned governing bodies is the requirement for port to prepare an appropriate waste management plan [13]. The use of port waste

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reception facilities would be examined, together with benefits and possible shortcomings of various influencing factors, and compulsory discharge of waste within the port.

## II. MATERIAL AND METHODS

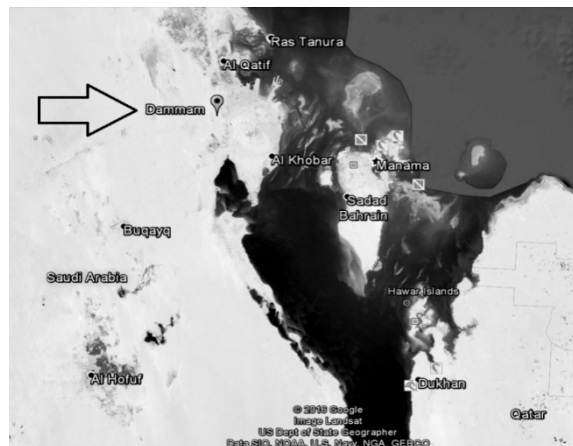
Methodology followed in this research work comprised four basic pillars that included:

- 1) Field survey, visual inspection and reconnaissance of study area at King Abdul-Aziz Dammam Port.
- 2) Sampling and sample collection.
- 3) Laboratory tests for quality parameters of significance and importance to project.

### 2.1 Preliminary investigations and site survey

Site visits were carried out for selected research area both inland and offshore locations. This helped in selecting sampling areas and potential research parameters of concern.

Map (1) is a map showing the location of Dammam city within the Arabian Gulf. Map (2) illustrates the research site boundaries.



Map (1) Dammam City.Source: <https://www.google.com.sa/maps?q=Dammam+City>

Dammam city is located on the east coast of KSA with coordinate  $26^{\circ} 17' N$   $50^{\circ} 12' E$ . The city is largest one in the eastern province. With an estimated population of over four million as the last statistical in 2012. It is one of the biggest economic cities in the kingdom. It contains the largest sea port on the Arabian Gulf and second only to Jeddah port in the Middle East region [4].



Map (2) King Abdul-Aziz port.Source: <https://www.google.com.sa/maps/place/King+Abdulaziz+Seaport>

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King Abdul Aziz Port is the principal port of Saudi Arabia in the Gulf and is located approximately mid-way along the Eastern Coast at coordinate of 26° 30' N 50° 12' E[4]. It is strategically placed to service the requirements of the oil industry, the continuous development of Riyadh and the major provincial cities in the Eastern and Central Provinces. The Port is fully self-sufficient with its own administration offices, mechanical and marine workshops, electrical, telephone and marine communication networks and water treatment plants. It has its own clinic, fire department and a large housing complex for port employees, with mosques and a supermarket. The whole port covers an area of around 193 Mm<sup>2</sup>[1].

## 2.2 Sampling and sample collection

Sampling points were identified and pin pointed by AlZamil Company which is handling routine and monitoring sampling issues within the port. These sampling points were as follows:

- Sample number 1: (S1) is taken from small craft area at the location of HUTA Company designated area.
- Sample number 2: (S2) is taken from Outer sea at sampling localities nominated by Port sampling authorities.
- Sample number 3: (S3) is drawn from the area devoted to RASCO Company.
- Sample number 4: (S4) is grabbed from the Shipping Yard of Albalaga Company.
- Sample number 5: (S5) is secured from Zamil Company first sampling locality adjacent to shore.

Samples were collected in accord with standard methods[5] procedures for sampling. Sampling bottles as sterilized in the laboratories of the Environmental Engineering Dept. were used for sample collection from selected sampling points. Samples were stored in fridges till experiment stage and time plans.

## 2.3 Laboratory instruments used in research work

The devices that were used in this research work included, but not limited to, Ion Chromatography (IC) and Atomic Absorption device and many other laboratory equipment and instruments.

- a) Inductively Coupled Plasma Optical Emission or ICP-OES. Inductively Coupled Plasma Optical Emission or ICP-OES ACTIVA S" (see plate 1) is an analytical technique used for elemental determinations. The sample is typically introduced into the ICP plasma as an aerosol, either by aspirating a liquid or dissolved solid sample into a nebulizer or using a laser to directly convert solid samples into an aerosol. Once the sample aerosol is introduced into the ICP torch, it is completely desolated and the elements in the aerosol are converted first into gaseous atoms and then ionized towards the end of the plasma.



Plate (1): Inductively Coupled Plasma Optical Emission.

ICP optical emission spectrometry is highly rated as a multipurpose analysis. It is well regarded as an environmental measurement technique, along with atomic absorption spectrometry and ICP mass spectrometry, and its use is expected to expand even further in the future.

1. For safety reasons all chemicals should be considered as a potential health hazard. The laboratory is responsible for maintaining a current awareness file of OSHA regulations regarding the safe handling of the chemicals specified in this method. A reference file of material handling data sheets should be made available to all personnel involved in the chemical analysis.
2. Reagents and Standards
  - Sample bottles: polyethylene of sufficient volume to allow replicate analyses of anions of interest.
  - Reagent water: double Distilled (Purified water), free of the anions of interest.
  - Water should contain particles Less than 0.20 microns.
  - Multi element Standard diluted from 100 ppm to 2.5 PPM (Al, Ba, Cd, ,Cr,Cu, Ni, Pb, Se,Zn)
  - Standards: 100 ppm standard diluted to: 2.5 PPM, 5.0 PPM, 10 PPM, 25 PPM and 50 PPM

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3. Preparing the Instrumentation: Standard operation procedure for ICP-OES: It is to be noted that Aragon GAS (Purity 99.999 %) is required for the operation of ICP-OES

Preparation of calibration standards follows the following procedure:

- Fill-up the chiller system (cooler) with deionized water to the maximum line.
  - Turn on the fume hood.
  - Turn on the Aragon gas tank valve. Make sure the pressure cylinder read at 2000 PSI and the ICP pressure valve read at 90 PSI.
  - Turn on the computer. Click on the Icon ICP 5.4 ACTIVA and select "Start Version 4". Click on Start on the top left, to start ICP. Place the Nebulizer tube into a beaker filled with Deionized water.
  - Click on Method Selection, type a title on the INPUT METHOD NAME, SELECT TYPE OF THE SOURCE (ICP), then click next.
  - If you making a new calibration, select FROM THE BASE OF ELEMENTS and select DEFAULT CONCENTRATION UNIT (AS EXAMPLE mg/l) AND Click next.
  - Select the elements by clicking on their symbols: Na, Cd, Pb.... And click next.
  - Type the concentration range of , low and high value. It can be done by highlight all elements, and press F 11 and click on next.
  - Select the wavelength of the elements you trying to analyze. This can be done by referring to the wavelength line that saved on the desk top and click on next, then click on finish.
  - Go to the main screen, click on task and sequences, new, and click on peaks search, then profile. Then click on Run. Use the highest standards to search for peaks.
  - For calibration, Click on Task and Sequence, Calibration, enter all calibration values, and then click on Analysis.
  - For analyzing samples, Click on Task and Sequences, click on analysis, Type samples ID, and click on run.
- b) Ion Chromatography (IC): Ion chromatographs are able to measure concentrations of major anions, such as fluoride, chloride, nitrate, nitrite, and sulfate, as well as major cations such as lithium, sodium, ammonium, potassium, calcium, and magnesium in the parts-per-billion (ppb) range. Concentrations of organic acids can also be measured through ion chromatography. The basic principle of the ion chromatography device that shall be used in this study is a form of liquid chromatography that measures concentrations of ionic species by separating them based on their interaction with a resin. Ionic species separate differently depending on species type and size. Sample solutions pass through a pressurized chromatographic column where ions are absorbed by column constituents. As an ion extraction liquid, known as eluent, runs through the column, the absorbed ions begin separating from the column. The retention time of different species determines the ionic concentrations in the sample. Chromatography includes some typical applications of ion. Plate (2) shows the Ion Chromatography equipment used at the Environmental Analysis laboratory at the Environmental Engineering Department of the College of Engineering of University of Dammam..



Plate (2): Ion Chromatography (Prominence UFLC).

Some typical applications of ion chromatography include:

- Drinking water analysis for pollution and other constituents

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- Determination of water chemistries in aquatic ecosystems
- Determination of sugar and salt content in foods
- Isolation of select proteins

EPA 300.0 [12] is followed as the method of testing and for sample preparation. Preparation of the Instrumentation is as follows:

- Turn on the machine, each button.
- Place injector and mobile phase tubes into right spot.
- Click on shimadzu LC solution
- Click on instrument 1 to connect to the software
- Create your method by clicking on post run
- Copy and paste old method, as new method
- Go to sample page, and click on wizard and create your file
- Load the method and press download

Ion chromatography, a form of liquid chromatography, measures concentrations of ionic species by separating them based on their interaction with a resin. Ionic species separate differently depending on species type and size. Sample solutions pass through a pressurized chromatographic column where ions are absorbed by column constituents. As an ion extraction liquid, known as eluent, runs through the column, the absorbed ions begin separating from the column. The retention time of different species determines the ionic concentrations in the sample.

### Sample Collection:

Water samples were collected in plastic polystyrene containers and bottles in accord with reference method U.S EPA 300. Five Samples transferred to 4 ml vials according to their numbering to be analyzed for chloride, nitrate, and sulfate, by High Performance Liquid Chromatography (SHIMADZU- HIC-20A Super).

### Parts of Ion Chromatography:

- Auto sampler: SIL -20Ai
- LC-20AD SP Prominence Liquid Chromatography ( Pump)
- DGU 20A 3R: degassing unit. take bubble out of the sample
- CTO-20AC SP: Column oven
- CDD-10A SP: Conductivity detector
- CBM- 20A: connect all instruments together plus with PC.

For safety all chemicals should be considered as a potential health hazard. The laboratory is responsible for maintaining a current awareness file of OSHA regulations regarding the safe handling of the chemicals specified in this method. A reference file of material handling data sheets should be made available to all personnel involved in the chemical analysis.

### Reagents and Standards

#### Mobile phase composition (Shim-pack IC-SA2)

Mobile Phase is a Composition of 12mM Sodium Hydrogen Carbonate and 0.6mM Sodium Carbonate solution. Sodium Hydrogen Carbonate,  $\text{NaHCO}_3$ : MW=84.01 Wako Pure Chemical Industries 191-01305 And Sodium Carbonate,  $\text{Na}_2\text{CO}_3$ : MW=105.99 Wako Pure Chemical Industries 507-05641 (MERCK) were used to prepare the mobile phase by Weighing 1.008g of Sodium Hydrogen Carbonate and 0.0636g of Sodium Carbonate in a 100 ml of Double Distilled water. The solution Agitated by using a stirrer until the reagent is completely dissolved and added to 900 ml of purified water to have 1 liter solution of mobile phase.

- Sample bottles: polyethylene of sufficient volume to allow replicate analyses of anions of interest.
- Reagent water: double Distilled (Purified water), free of the anions of interest.
- Water should contain particles Less than 0.20 microns.



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- Single Standards are prepared from five different salts as a combination of multi element standards as following:
- Potassium Fluoride Dihydrate (Molar Mass 94.13)
- Sodium Chloride Extra Pure (Molar Mass 58.44)
- Sodium Nitrate (Molar Mass 84.99)
- Sodium Phosphate Dibasic Anhydrous ( Molar Mass 141.94)
- Sodium Sulfate Anhydrous (Molar Mass 142.04)

Dividing the molar mass of each salt by the interest anions to have the exact mass needed to prepare 1000 PPM( Part per million) Concentration in on Milliliters solution (mg/L):4.955 g( Potassium Fluoride Dihydrate+1.648 g (Sodium Chloride)+ 1.3707 g (Sodium nitrate) + 1.495 g( Sodium Phosphate Dibasic Anhydrous) + 1.479 g( Sodium Sulfate Anhydrous) Added in to 1000 ml Volumetric Flask ( Solution A). Solution A diluted to 100 ppm (Solution B) by measuring 10 ml of solution A added to 90 ml of purified water to 100 ml plastic volumetric flask. Solution B used to make the following Calibration STD in 4 ml Liquid Chromatography vials:

6.25 PPM: 0.25 ml (solution B) + 3.75 ml Purified water

12.5 PPM: 0.50 ml (solution B) + 3.50 ml Purified water

25 PPM: 1.0 ml (solution B) + 3.00 ml Purified water

50 PPM: 2.0 ml (solution B) + 2.00 ml Purified water

75 PPM: 3.0 ml (solution B) + 1.00 ml Purified water

100 PPM: 4.0 ml (solution B) + 0 ml Purified water

Preparing the Instrumentation:

- Turn on the machine, each button.
- Place injector and mobile phase tubes into right spot.
- Click on shimadzu LC solution
- Click on instrument 1 to connect to the software
- Create your method by clicking on post run
- Copy and paste old method, as new method
- Go to sample page, and click on wizard and create your file
- Load the method and press download

Loading of Standards and Samples:

The six levels Calibration standards placed on the auto sampler as well as the 6 samples. ICV and ICB placed immediately after calibration

- Atomic Absorption Spectrophotometer: Model Type: ICE-3000 (see plate 3). This equipment is using for quantitative determination of chemical elements using the absorption of optical radiation (light) by free atoms in the gaseous state. Accuracy: 0.5–5%.



Plate (3) Atomic Absorption Spectrophotometer

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- d) Consort Multi-Parameter Analyser. Model Type: C3040 (see plate 4). This equipment is using for measurement of pH, Conductivity. Accuracy: (-2...+16 pH), 0...2000  $\mu\text{S}/\text{cm}$

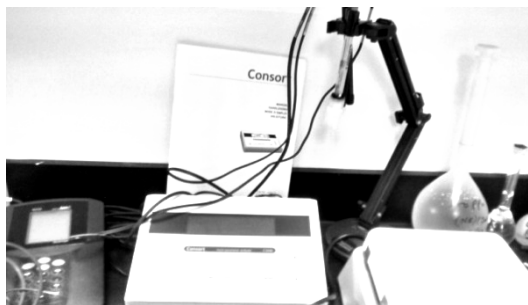


Plate (4) Consort Multi-Parameter Analyser

- e) UV VIS Spectrophotometer with RFID Technology: Model Type: DR 6000 (see plate 5). This equipment is using for pre-programmed testing methods, including high speed wavelength scanning across the UV and Visible Spectrum. Wavelength Accuracy:  $\pm 1$  nm, Photometric Accuracy: 5 mAbs at 0.0-0.5 Abs.



Plate (5) UV VIS Spectrophotometer with RFID Technology

- f) COD Digester (see plate 6): This equipment is using for measurement of the Capacity of Water to Consume Oxygen During the Decomposition of Organic Matter and the Oxidation of Inorganic Chemicals such as Ammonia and Nitrite.



Plate (6) COD Digester.

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A turbidity meter Model Type: HI 98703 is used in measurement of Turbidity. Accuracy: high accuracy (+0.02 NTU).

A DO meter, model type: Hach Session 8(Box 389) is used for measurement of DO. Accuracy: Temperature Accuracy  $\pm 0.3^{\circ}\text{C}$ ,  $\pm 0.1\text{ mg/L}$  for 0.1–8 mg/L  $\pm 0.2\text{ mg/L}$  for greater than 8.0 mg/L.

## 2.4 Wastewater treatment plant field data collection

Site inventory evaluation was conducted at residential area serving port employees to gather background data and information that would reveal the status of sanitation and wastewater handling that locality in terms of:

- existing wastewater treatment plant, if any.
- Identification of existing types of technologies or systems utilized at plant site.
- Evaluation of status and level of each existing onsite treatment plant, design capacity, year of construction, and selected location.
- Interviews conducted with personnel, officials, engineers, TP operators and workers at concerned municipality for the wastewater treatment plant.
- Repeated visits to site and locality.

An appropriate research questionnaire was designed to collect relevant and sufficient data and information for the treatment plant units and processes. The questionnaire is speculated to assist in collecting relevant information towards monitoring of treatment plants in the study area. Questions addressed basic information: raw wastewater source, current treatment technologies(primary, secondary and tertiary), operational issues, technical history for plant, process parameters that may affect efficiency of plant. 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.

## III. RESULTS AND DISCUSSIONS

The purpose of the study is to analyse the uniformity and quality of the Dammam port water, using a collection of 5 different sites. The main goal is to test the levels of metals and trace elements, and compare their concentration to the acceptable levels.

Wastewater samples were collected in plastic containers and polystyrene bottles in accord with sampling reference methods and procedures. Table (1) illustrates results attained by Inductively Coupled Plasma Optical Emission or ICP-OES.

**Table (1) Results attained by Inductively Coupled Plasma Optical Emission.**

Sample ID	Al	Ba	CD	Cr	Cu	Ni	Pb	Se	Zn
S1 small craft area (HUTA Company)	0.06	0.00	0.00	0.00	0.00	2.92	0.00	3.63	0.05
S2 Outer sea	0.05	0.00	0.00	0.00	0.00	3.03	1.12	3.96	0.19
S3 Company RASCO	0.05	0.00	0.00	0.00	0.00	6.33	0.00	3.10	0.07
S4 Shipping Yard(Albalaga)	0.06	0.00	0.00	0.00	0.00	2.99	0.00	3.40	0.01
S5 Zamil Company	0.14	0.00	0.16	0.00	0.00	2.81	0.00	13.2	0.01

Figure (1) shows values of tested components of Al, Ba, CD, Cr, Cu, Ni, Pb, Se and Zn. As could be seen from Fig. (1) there is distinct variation among tested components and indicators of pollution. Nonetheless, all of test results do not show existence of alarming pollutional load within tested areas.



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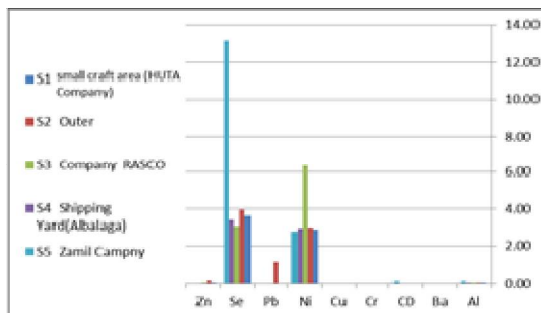


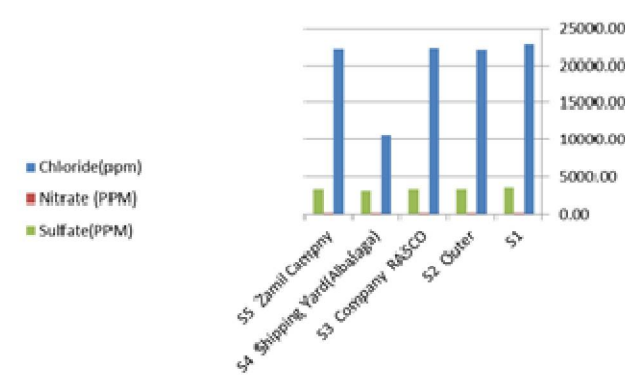
Figure (1) Values of tested components.

Ion chromatography is used for determination of fluoride, chloride, nitrate, phosphate and sulfate according to US EPA 300.0. Results were as tabulated in table (2).

**Table (2) Ion chromatography is determinations.**

Sample ID	Chloride(ppm)	Nitrate (ppm)	Sulphate(ppm)
S1 small craft area (HUTA Company)	22845	59	3483
S2 Outer	22043	57	3287
S3 Company RASCO	22228	56	3231
S4 Shipping Yard(Albalaga)	10694	54	3058
S5 Zamil Company	22116	56	3214

Figure (2) shows a Plot showing the concentration of anions tested within study area. The changing quality parameters did not show disturbing pollution threats in these areas.



**Figure (2) A Plot showing the concentration of anions.**

Tables (3) and (4) illustrate laboratory findings for determining potential pollutant parameters at Dammam Port including: Chloride, Nitrate, Sulphate, pH, Conductivity, Temperature, Turbidity, Ammonium, TCOD, DO initial, Total solids, suspended solids, TDS, Phosphate, Alkalinity, lead and zinc.

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**Table (3) Determination of chloride, nitrate and sulphate in tested samples.**

Sample ID	Chloride (ppm)	Nitrate (ppm)	Sulphate (ppm)
S1 small craft area (HUTA Company)	22845	59	3483
S2 Outer	22043	57	3287
S3 Company RASCO	22228	56	3231
S4 Shipping Yard(Albalaga)	10694	54	3058
S5 Zamil company	22116	56	3214

From obtained results there is no confirmed pollutants in excess of allowed limits (see tables 5 and 6). As such, it is concluded that the port area represents no contamination hazards or pollution threats.

**Table (4) Laboratory investigations of collected samples from port neighborhood.**

Sample ID	S1 small craft area (HUTA Company)	S2 Outer	S3 Company RASCO	S4 Shipping Yard(Albalaga)	S5 Zamil Company
pH	7.54	7.8	7.8	7.75	7.3
Conductivity	32.8	33.4	33.6	33.1	33.4
Temperature	22.1	22.1	21.8	21.9	21.8
Turbidity	1.3	2.1	1.1	1.7	9.9
Nitrate	0.4r	0.42	0.43	0.66	1.2
Ammonium	0.15	0.15	0.15	0.13	0.14
T COD	341	155	326	266	324
DO initial	4.18	4.51	4.76	4.21	4.34
Nitrite	0.01	0.03	0.02	0.03	0.03
Total solids	21174	21579	21945	21573	21760
S Solids	174	179	445	374	360
TDS	2.10E+04	2.10E+04	2.20E+04	2.10E+04	2.10E+04
Sulphate	450	463	407	454	475
Phosphate	0	0	0	0	0.005
Alkalinity	135	146	149	134	154
Pb	0	0	0	0	0
Zn	0.32	0.24	0.23	0.23	0.26

Note: 1.All the values for parameters measured are in mg/l except Turbidity( NTU) , conductivity(ms/cm).  
2. TCOD, Phosphate, Ammonium , Nitrate ,Nitrite, Sulphate, Phosphate Concentration has been determined by Hach Lang kits ( DR 6000 MODEL) &Pb, Zn by AAS ( Atomic Absorption Spectrophotometer )

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**Table (5) Ministry of Water and Electricity standards [6, 8, 9]**

Constituents	Maximum level		
	Raw wastewater	Secondary effluent, restricted irrigation	Tertiary effluent, unrestricted irrigation
COD, mg/L	1000	NI	NI
BOD, mg/L	500	40 (monthly average)	10 (monthly average) 15 (weekly average)
SS, mg/L	600	40 (monthly average)	10 (monthly average) 15 (weekly average)
TKN, mg/L	NI	NI	NI
NH <sub>3</sub> , mg/L	80	5	5
NO <sub>3</sub> , mg/L	NI	NI	NI
NO <sub>2</sub> , mg/L	NI	10	10
PO <sub>4</sub> , mg/L	25	NI	NI
Fecal coliform, MPN/100mL	NI	1000	2.2 (weekly average) 23 (at any sample)
Total coliform, MPN/100mL	NI	NI	NI

**Table (6) Ministry of Municipalities and Rural Affairs standards for treated wastewater [7, 10, 11].**

Constituents	Maximum level	
	Restricted irrigation	Unrestricted irrigation
COD, mg/L	NI	50
BOD, mg/L	40	10
SS, mg/L	40	10
TKN, mg/L	NI	NI
NH <sub>3</sub> , mg/L	5	5
NO <sub>3</sub> , mg/L	NI	NI
NO <sub>2</sub> , mg/L	10	10
PO <sub>4</sub> , mg/L	NI	NI
Fecal coliform, MPN/100mL	1000	2.2
Total coliform, MPN/100mL	NI	NI

## IV. CONCLUSIONS

From the research work carried herein the following conclusions emerged:

- 1) Water quality determination from within the port indicated the absence of pollution or contamination resulting from import and export activities. Investigated parameters were within acceptable limits for: pH, conductivity, temperature, turbidity, nitrates, ammonium, COD, initial DO, total solids, TDS, sulfates, phosphates, alkalinity, chlorides, conductivity, aluminum, barium, cadmium, chromium, copper, nickel, selenium, lead and zinc.

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- 2) Key performance indicators, KPIs, recommended for port waste engineering and management included: Accountability and Liability Indicators, Administration and Support Services Indicators, Community Service, Raising Public Awareness & Participation Indicators, Context and Framework Indicators, Customer Service Functions Indicators, Facilities and Equipment Indicators, Financial Planning, Economic Performance & Management Indicators, Functioning and Operational Indicators, Governance and Administration Indicators, Health, Wellbeing and Environs Related Indicators (Patterns of Cleanliness Behavior), Research and Development Indicators, Service Performance Indicators and Training & capacity building Indicators. These KPIs may be used in port waste management, monitoring and control.

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