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Research Article

TRACE METALS TRAJECTORY OF WASTEWATER AND THEIR TOXICITY TO MARINE FISH USING NUMERICAL SIMULATION MODEL

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Abstract- The adverse ecological conditions caused to the commercial Seabreams: *Diplodus sargus sargus L., Rhabdosargus sarba F., and Crenidenscrenidens F.,* fish was observed due to the increase in wastewater pollution. Using DESCAR-3.2 software program, trace metals trajectories from the drain outfalls was modeledbesides, the laboratory assessment of static toxicity and bioaccumulation tests. The wastewater discharged from seven drain outfalls (SI-SVII) showed high trace metals sequence (Zn>Fe>Cu>Pb>Cr>As>Hg) during winter than in the summer seasons. Toxicity tests showed high trace metals sensitivity in the sequence of *C. crenidens*>*D. sargus*>*R. sarba*. Bioaccumulation factor (BAF) >1 in these fish exposed for 30d indicated significant trace metals accumulation from wastewater. Fish indicating BAF <1 suggested the trace metals in their body parts was due to the adsorption process or through victuals. This novel multidimensional study not only labelled the sampled fish species as bio-indicator and bio-accumulator to wastewater pollution but also, validated the specific seasonal orientation and dispersion of wastewater into the marine environment unlike earlier findings in the region.

Keywords- Bio-indicator, Elemental Analysis, Marine Environment, Numerical Model

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Introduction

Persistent toxicity and bioaccumulation of pollutants constituting trace metals is found to cause serious threats to the marine ecosystem. Domestic and industrial wastes are discharged from the drain outfalls into the sea. The wastewater discharged into the sea depends on the effluent volume, velocity and the direction of the water current [1-2]. The dispersed effluent accumulated at the bottom of the seabed. The differences in density and natural turbulence in the shallow seas made the wastewater buoyant, rose to the surface as buoyant-jet, gradually dispersed and, mixed with seawater when they entered the marine environment[3-5].The present study observed analogous phenomenon in the marine environment of Kuwait to that of the earlier studies as described above and hence, the investigation.

The Kuwait Bayis subjected to single-directional water flow, low velocity of water current, hydrological and seasonal changes. Kuwait Bay showed similar attributes of 'disturbed ecosystem' like some Bays elsewhere the globe [6-8]. Comparatively, high trace metals levels was observed in the gills, liver and muscle tissues of commercial fish inhabiting the Bay than the metals levels in deep-sea fishes [7, 9-12]. Among the fishes in Kuwaiti waters, three species of sea breams that were caught near the vicinity of wastewater outfalls showed varying trace metals concentrations in their body tissues. Thus, three selected fish that are commercially viable and abundantly observed throughout the seasons of the year was evaluated to study their influence of trace metals pollution from the wastewater discharges. *Rhabdosargus sarba F*., (mean TL: 45cm) – Gold line Seabream, inhabiting the shallow water sis a large, solitary school fish that enters brackish water areas. They feed on benthic invertebrates and aquatic macrophytes [13]. *Diplodus sargus sargus L*., (mean TL: 22cm) - White Sea bream inhabiting the coastal rocky areas frequents at dawn and feeds on shellfish and benthic invertebrates [13]. *Crenidens crenidens F*., (mean TL: 28cm) – Karanteen sea bream, inhabiting near the muddy areas feeds on algae and invertebrates [13]. Earlier ecological studies showed significant relationship between the bioaccumulation of trace metals and in the body organs of these fish [14-19]. Non-essential trace metals were found to accumulate more than essential metals in the body organs of such fish species [12,20-22]. However, the possible trace metals dispersion route from wastewater drain out falls that accumulated in the fish were less evidenced. Therefore, the present study also determined: (a) the direction and quantification of trace metals dispersion for a given distance using Buoyant-jet model (DESCAR program-ver. 3.2: Canarina Environmental Software, Spain), (b) the factors of pollutant's dispersion and, (c) trace metals toxicity and bioaccumulation factor (BAF) in the gills, liver and muscle tissues of the three selected fish and statistically validated by Probit Program. This study also supports the preventive measures to consumption of fish caught from the perturbed marine environment.

Material and Methods

Sampling sites

This study chose permanent concrete drain outfalls(SI-SVI) constructed along the Kuwait Coast that let domestic and industrial wastewater into the marine environment and, a reference drain outfall (S-VII) off, the Kuwait Coast during summer and winter seasons [Fig-1], [Fig-2]. Drain outfalls constructed along the southern region of Kuwait discharged a very low volume of wastewater and hence, not investigated.

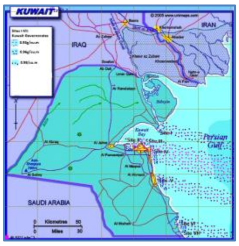

Fig-1 Sampled sites indicating the wastewater dispersion from drain outfalls during the summer season

Wastewater sample collection and analysis

Employing Vandorn's water sampler (2L), wastewater samples (6720 nos.) was collected from two loci at the entry point of each drain outfall (12 drain outfalls x 2loci/drain x 10 replicates x 7 locations x 2 seasons/year x 2 years). A 0.45µm membrane filter was used to filter wastewater and analyzed for trace metals. The standard methodology [23] was followed to pre-concentrate the trace metals in the wastewater and measured in the ICP-MS. Certified Reference Materials (CRM-403: marine water), trace metals standards (ICP grade) and blanks were used for quality control and assurance [23].

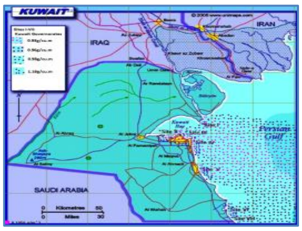

Fig-2 Sampled sites indicating the wastewater dispersion from drain outfalls during the winter season

Numerical simulation of trace metals discharges from wastewater drain outfalls

The sampling site maps [Fig-1], [Fig-2] were superimposed with the corresponding coordinates of the DESCAR-3.2 program graphical interface. Effluent discharges flow rate, velocity, water depths, discharge density and mean trace metals concentrations from the Kuwait coastline drain outfalls were determined using Channel flow meter, water depth finder, water density meter and ICP-MS respectively. These data incorporated into the DESCAR-3.2 graphical interface questionnaire obtained the direction, intensity and dispersion path of trace metals concentrations that dispersed from the wastewater outfalls into the sea.

DESCAR-3.2 Program (Canaria, Spain) software used time-dependent Gaussian equation in the Buoyant-Jet model with graphical user interface and created dynamic numerical simulations of wastewater dispersion route into the seawater. This model simulated the pollutant dispersion located near the coast with little depth [24]. The pollutant concentrations at a distance x (m) on the X-Axis and at a distance y (m) on the Y-axis was given by:

$$c=c_c\exp[-(r/b)^2] \qquad [1]$$

Where in, 'c' is the trace metals concentrations, 'r' the distance from the point to the center of line that forms the polluting plume, 'c_c' the pollutant concentrations in the center of plume line and 'b' is the plume half-width. The program simulates the linked relationship between buoyancy dominated regimes and transitions to obtain vertical and horizontal buoyant jet solutions in a cross flows respectively. This simulation is given by equation:

$$z/L_b=c_{xy}(x/L_m)^{1/3}] \qquad [2]$$

Wherein, 'z' is the vertical coordinate, 'L_b' is the plume-cross flow length scale, 'C_{xy}' constant of proportionality, 'x' is the horizontal downstream coordinate in global coordinate system, 'L_m' is jet to cross flow length scale. The DESCAR-3.2 program calculated the above formulae [1 & 2] when the inputs were supplemented and the superimposed map interpolated the orientation and dispersion of trace metals in wastewater from each drain outfalls.

Analysis of trace metals in the selected marine fish

This study chose three commercially important sea breams namely, *Crenidens crenidens F., Diplodus sargus sargus L.,* and *Rhabdosargus sarba F.,* inhabiting in and around the drain outfalls. Uniform sizes of *C. crenidens, D. sargus* and *R. sarba* (28±2cm, 22±5cm, 45±5cm) were caught using drag, trap nets and anglers respectively. Gills, liver and muscle tissues of these three fish (10 replicates each) were dissected. Tissues (each 2g) were cleaned in deionized distilled water and dried in a hot air oven (Gallen Kamp-II) at 45°C until dryness. Samples were individually treated with 5% nitric acid and digested in an automated microwave digester (Ethos 1, Milestone, Italy). The digested samples were determined for trace metals (Cu, Zn, Fe, Pb, Cr, As) in the ICP-MS [23]. Total mercury (Hg) in the fish samples was analyzed using a direct mercury analyzer (DMA-80, Milestone, Italy, compliant to USEPA 7473 method). Quality assurance and quality control were undertaken by spiking the samples, internal blanks and standard mercury solution (100mg/l). The precision of the instrument was quality assured using reference material (CRM: DORM-4 fish protein, National Research Council, Canada). Recoveries of samples (97-98%) in line with the certified values were considered for quality elemental measurements.

Trace metals toxicity and bioaccumulation in the selected fish

Toxicity tests (LC_{50}) in the laboratory involved the acclimation of the three selected fish (10 replicates, each) for 24h. In the experimental tanks with filtered wastewater, stock solution of each trace metal (Cu, Fe, Zn, As, Se,Cr, Hg: ICP grade) was added separately to produce the respective LC_{50} test concentrations. Trace metals was renewed every 24h to prevent reduction in the toxicant levels [8] (El-Moselhy *et al*., 2014).LC_{50} at 72h were calculated using Probit Program [25]. These tests were conducted after the permission granted by the institutional and local statutory ethics.

Bioaccumulation of trace metals assessed the 30d exposure of the selected fish for trace metals concentrations at LC_{15} and bioaccumulation factor (BAF) in each tank [18, 26]. Ten fish from a tank containing wastewater without the addition of trace metals were sacrificed to serve as control. Following the standard methods, the three fish was fed to satiety with brine shrimp larvae to facilitate complete consumption and assimilation of feed instead of unconsumed food traces in the experimental tank. Excreta in the tanks were removed every day. Water exchange (5%) was provided and trace metals concentrations were replenished with the respective trace metals dosage. Fish reared in control and in the experimental tanks were selected at random and sacrificed after 30d exposure. Fish liver, gills and, muscles tissues were dried in an oven (Gallen Kamp II) at 60°C overnight until constant weight. The dried tissues (0.2g) were added with 5% nitric acid and digested in the automatic microwave digester (Ethos-1, Milestone Italy). Fish tissues were measured for the selected trace metals and Hg in the ICP-MS and DMA-80 respectively. Standard methods were followed to maintain quality control and assurance [23].

Results

The main criteria of this study was based on the continuous wastewater discharges from the concrete drain outfalls into the sea without adequate treatment and the upsurge of pollutants in the marine ecosystem [Fig-1], [Fig-2]. Trace metals concentrations was found elevated in wastewater during winter than in the summer season [Fig-3]. The extent of wastewater dispersion and total mean volume of trace metals concentrations from each drain outfalls encompassing the six Kuwait Coast was validated by DESCAR-3.2 program.

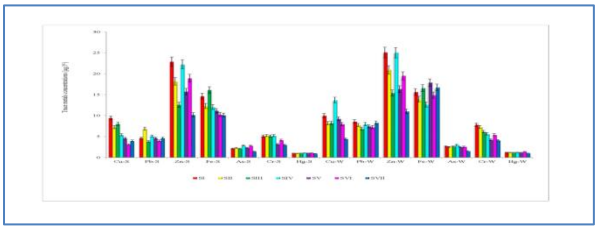

Fig-3 Site-wise trace metals concentrations in wastewater from seven sites of Kuwait's drain outfalls during the two seasons

S: summer; W: winter; SI-SVI: drain outfalls in Governorates; SVII: reference drain

Metals-wise and site-wise wastewater analysis revealed elevated sequence of trace metals, Zn> Fe>Cu>Pb>Cr>As>Hg and SI>SIV>SII>SVI>SV>SIII>SVII, respectively [Fig-3]. Moderate to low trace metals concentrations were observed in SVI and SV. Trace metals concentrations was very low in samples collected from semi-permanent drain outfall (SVII). Among the three test species, trace metals concentrations was found high in *R. sarba* followed by *D. sargus* and *C. crenidens* [Fig-4]. Observation showed high trace metals concentrations in the sequence of Zn>Fe>Cu>Cr>Pb>As>Hg in the liver followed by gills and muscles tissues in all the three fish species [Fig-5].

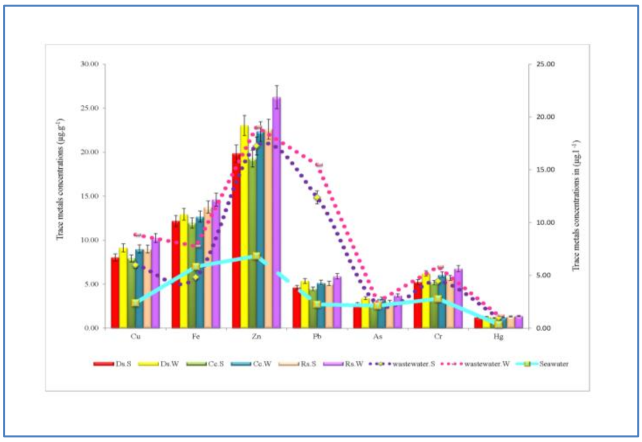

Fig-4 Mean metals-wise concentrations in the three fish species, wastewater and seawater during the two seasons

Ds: *D. sargus*; Rs: *R. sarba*; Cc: *C. crenidens*; S: summer; W: winter

Site-wise analysis revealed high trace metals concentrations in the sequence of SI>SIV>SIII>SII>SVI>SV>SVII in the three fish species during the two seasons [Fig-5]. Fish caught from SI to SIV drain outfalls showed high trace metals in the liver, gills and muscle tissues.

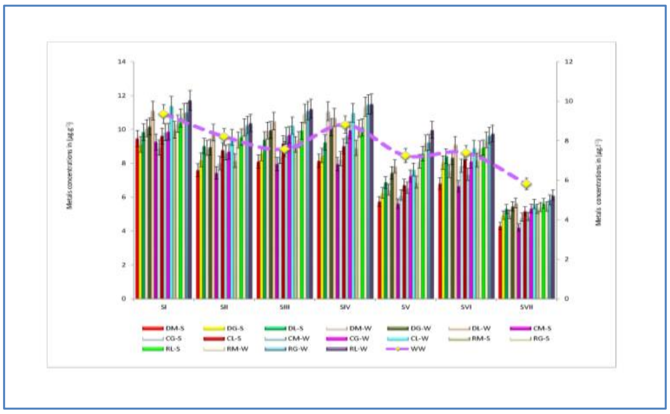

Fig-5 Site-wise trace metals concentrations in liver, gills, muscle tissues of three fish species

SI-SVII: drain outfalls; M: muscle, G: gills, L: liver, S: summer, W: winter, D: *Dipplodus sargus*; C: *Crenidens crenidens*; R: *Rhabdo sargus sarba*

Toxicity tests showed high sensitivity of Hg at 0.4 µg.l^{-1} than the other trace metals in *C. crenidens* when compared to *D. sargus and R. sarba* [Table-1-2]. An exposure study (72 h) validated by Probit analysis [25] (USEPA, 1993) confirmed, *C. crenidens* to be highly effective at LC_{50} concentrations in the sequence of Hg (0.83µg.l^{-1})>As (4.33 µg.l^{-1})>Pb (4.73 µg.l^{-1})> Cr (5.62 µg.l^{-1})> Cu (9.13 µg.l^{-1})> Fe (12.29 µg.l^{-1})>Zn (18.67 µg.l^{-1}) [Table-1], [Table-2]. Statistical test by Probit Program using Chi-square (χ^2) distribution showed significant difference in all the calculated exposed concentrations against the χ^2 table value [Table-1], [Table-2].

Table-1 *Toxicity and bioaccumulation (30 d exposure) of essential metals in the three marine fish*

Metals	Conc.	Exp. conc. (µg.L^{-1})	95% CI-Lower	95% CI-Upper	χ2	Mortality	Mean metals (µg.g^{-1})	Mean BAF (b/a)
				Wastewater (a)				
Cu	7.42±1.11							
Fe	13.94±2.15							
Zn	18.16±2.16							
Cr	5.13±1.02							
Pb	6.29±1.06							
As	2.39±0.59							
Hg	1.09±0.14							
				Toxicity test (b)				
Cu-Rs	Control	7.70	3.84	10.14	1.33*	-	9.53 ±1.49	1.29†
	SL (LC_{15})	12.30	8.81	14.37	1.33*	-	9.62 ±1.50	1.30†
	PA (LC_{50})	17.93	15.61	20.91	1.33			
Cu-Ds	Control	6.03	2.01	8.72	1.38*	-	8.46 ±1.32	1.14†
	SL (LC_{15})	11.35	7.14	13.76	1.38*	-	8.59 ±1.34	1.16†
	PA (LC_{50})	18.86	15.92	24.72	1.38			
Cu-Cc	Control	5.3	2.4	7.37	0.39*	-	8.41 ±1.31	1.13†
	SL (LC_{15})	9.13	6.09	11.05	0.39*	1	8.47 ±1.32	1.14†
	PA (LC_{50})	14.13	11.89	16.59	0.39			
Fe-Rs	Control	9.86	6.27	11.84	1.44*	-	13.97 ±2.18	1.00†
	SL (LC_{15})	13.63	11.04	15.11	1.44*	-	14.19 ±2.21	1.02†
	PA (LC_{50})	17.69	16.15	19.77	1.44			
Fe-Ds	Control	9.58	6.47	11.39	0.56*	-	12.37 ±1.93	0.89
	SL (LC_{15})	12.97	10.64	14.35	0.56*	-	12.56 ±1.96	0.90
	PA (LC_{50})	16.54	15.11	18.14	0.56			
Fe-Cc	Control	5.43	2.79	7.08	1.30*	-	12.28 ±1.91	0.88
	SL (LC_{15})	8.54	6.2	9.92	1.30*	-	12.32 ±1.92	0.88
	PA (LC_{50})	12.29	10.76	14.27	1.30*			
Zn-Rs	Control	14.14	9.53	16.84	0.50*	-	23.95 ±2.84	1.32†
	SL (LC_{15})	19.18	15.7	21.25	0.50*	-	24.43 ±2.78	1.35†
	PA (LC_{50})	24.51	22.36	26.86	0.50			
Zn-Ds	Control	13.16	9.67	15.11	0.56*	-	20.93 ±2.62	1.15†
	SL (LC_{15})	16.79	14.36	18.2	0.56*	-	21.43 ±2.73	1.18†
	PA (LC_{50})	20.41	18.98	21.96	0.56			
Zn-Cc	Control	9.34	5.11	11.59	1.26*	-	19.93 ±2.51	1.10†
	SL (LC_{15})	13.71	10.64	15.38	1.26*	-	20.79 ±2.58	1.15†
	PA (LC_{50})	18.67	16.85	21.94	1.26*			

Exp.: exposure concentrations, SL: sublethal concentrations, PA: Probit analysis, CI: confidence intervals, χ2: Chi square, *: χ2 significance between control, LC15 test and probit analysis (LC50) at 0.05 level at 0.05 level, †BAF >1: significant bioaccumulation factor, Rs: *R sarba*, Ds: *D. sargus*, Cc: *C. crenidens*, LC: lethal concentrations

Table-2 *Toxicity and bioaccumulation (30 d exposure) of non-essential metals in the three marine fish*

Metals	Conc.	Exp. conc. (µg.L^{-1})	95% CI-Lower	95% CI-Upper	χ2	Mortality	Mean metals (µg.g^{-1})	Mean BAF (b/a)
Cr-Rs	Control	3.43	1.24	4.98	0.68*	-	5.41 ±0.84	1.05†
	SL (LC$_{15}$)	6.39	3.99	7.82	0.68*	-	5.49 ±0.85	1.07†
	PA (LC$_{50}$)	10.52	8.81	13.06	0.68			
Cr-Ds	Control	3.84	2.03	4.86	0.87*	-	4.88 ±0.76	0.95
	SL (LC$_{15}$)	5.82	4.41	6.62	0.87*	1	4.99 ±0.78	0.97
	PA (LC$_{50}$)	8.14	7.25	9.57	0.87			
Cr-Cc	Control	2.72	1.06	3.06	1.40*	-	4.79 ±0.74	0.93
	SL (LC$_{15}$)	3.75	2.6	4.44	1.40*	1	4.83 ±0.75	0.94
	PA (LC$_{50}$)	5.62	4.84	6.63	1.40			
Pb-Rs	Control	4.93	3.14	5.92	1.44*	-	3.32 ±0.51	0.53
	SL (LC$_{15}$)	6.82	5.52	7.56	1.44*	1	3.37 ±0.52	0.54
	PA (LC$_{50}$)	8.84	8.07	9.89	1.44			
Pb-Ds	Control	3.07	1.69	3.92	0.90*	-	2.98 ±0.46	0.47
	SL (LC$_{15}$)	4.68	3.5	5.37	0.90*	1	3.09 ±0.48	0.49
	PA (LC$_{50}$)	6.55	5.79	7.5	0.90			
Pb-Cc	Control	1.3	0.37	2.03	0.79*	-	2.94 ±0.45	0.47
	SL (LC$_{15}$)	2.67	1.49	3.38	0.79*	1	3.06 ±0.47	0.49
	PA (LC$_{50}$)	4.73	3.85	6.06	0.79			
As-Rs	Control	1.41	0.47	2.11	1.72*	-	6.19 ±0.96	2.59†
	SL (LC$_{15}$)	2.71	1.6	3.39	1.72*	1	6.25 ±0.97	2.62†
	PA (LC$_{50}$)	4.57	3.75	5.67	1.72			
As-Ds	Control	1.35	0.45	2.03	1.21*	-	5.68 ±0.88	2.38†
	SL (LC$_{15}$)	2.62	1.53	3.29	1.21*	1	5.73 ±0.89	2.40†
	PA (LC$_{50}$)	4.45	3.63	5.49	1.21			
As-Cc	Control	1.21	0.37	1.87	1.29*	-	5.55 ±0.86	2.32†
	SL (LC$_{15}$)	2.45	1.38	3.12	1.29*	2	5.63 ±0.88	2.36†
	PA (LC$_{50}$)	4.33	3.49	5.39	1.29			
Hg-Rs	Control	0.99	0.3	1.59	1.10*	-	1.29 ±0.20	1.19†
	SL (LC$_{15}$)	2.1	1.15	2.74	1.10*	1	1.35 ±0.21	1.25†
	PA (LC$_{50}$)	3.83	3.02	4.74	1.10			
Hg-Ds	Control	0.67	0.22	1.02	1.21*	-	1.19 ±0.16	1.09†
	SL (LC$_{15}$)	1.31	0.76	1.64	1.21*	1	1.24 ±0.19	1.14†
	PA (LC$_{50}$)	2.22	1.81	2.74	1.21			
Hg-Cc	Control	0.16	0.03	0.29	0.33*	-	1.12 ±0.12	1.03†
	SL (LC15)	0.4	0.18	0.56	0.33*	2	1.18 ±0.15	1.08†
	PA (LC$_{50}$)	0.83	0.6	1.07	0.33			

Exp.: exposure concentrations, SL: sublethal concentrations, PA: Probit analysis, CI: confidence intervals, χ2: Chi square, *: χ2 significance between control, LC15 test and probit analysis (LC50) at 0.05 level, †BAF >1: significant-bioaccumulation factor, Rs: *R sarba*, Ds: *D. sargus*, Cc: *C. crenidens*, LC: lethal concentrations

Bioaccumulation factor (BAF) in the three fish exposed for 30d was >1 indicating a significant trace metals bio accumulation in these fish from wastewater except Iron (Fe) and Lead (Pb) [Fig-6] ranging BAF 1.20 to 1.60).BAF was high in *R. sarba* followed by *D. sargus* and *C. crenidens*. This study showed high trace metals concentrations and BAF in the small fish. Irrespective of the three fish, high BAF was found in the liver followed by gills and muscle tissues [Fig-6]. High trace metals BAF was observed in the fish reared in SVI drain outfalls wastewater when compared to the BAF in fish reared in the other wastewater drain outfalls [Fig-6].

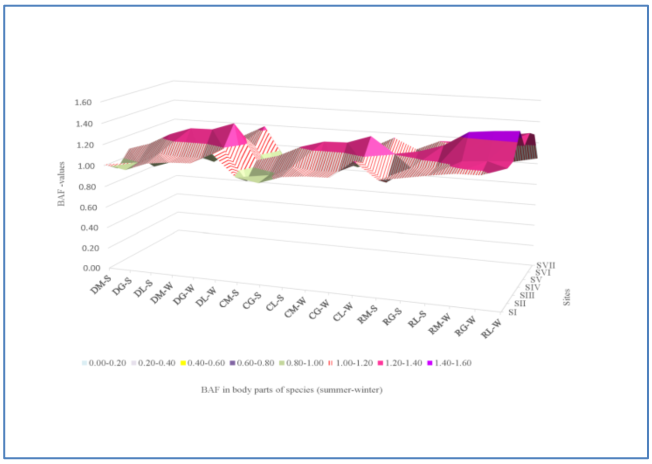

Fig-6 Bioaccumulation Factor (BAF) analysis of fish and during the summer and winter seasons

D: *Dipplodus sargus*; C: *Crenidenscrenidens*; R: *Rhabdo sargus sarba;* M: muscle, G: Gills, L: liver; S: summer; W: winter

Discussion

Stagnation of wastewater, low water current in the Kuwait Bay causing a definite wastewater dispersal pathway in the Kuwait Coast and, untreated domestic wastewater discharges attributes for the seasonal changes in the elevated trace metals concentrations. Researchers [3-5,9-10,24] observed elevated trace metals concentrations with seasonal variations but, revealed no links to trace metals dispersion trajectories into the marine waters. High trace metals concentrations from SI drain outfalls attributes to the accidental or untreated wastewater discharges from the desalination and the thermal plants. The elevated trace metals concentrations in wastewater sampled from SII and SIV attributed to the impact of low water current, domestic effluent discharges into the Bay and the mixing from the water-sediment interface. These observations were found in agreement with the earlier studies [6-7]. Despite the presence of oil industries, the moderate to low trace metals concentrations in SV and SVI sites justifies the stringent measures undertaken to discharge treated wastewater by the municipal treatment bodies. Very low concentrations in Site VII is due to the least volume of effluent discharged into the open sea.

The high trace metals concentrations in the three fish species when compared to the trace metals concentrations in wastewater validating the possibility of bioaccumulation in their body system [Fig-4]. The high trace metals concentrations in the three fish parts is primarily related to the differences in ecological requirements, large quantity of metallothioneins inclusion in the liver tissue, adsorption of metals on the fish gill surface and metals bioaccumulation from the industrial and domestic wastewater discharges especially when they are untreated and discharged occasionally into the marine environment [8,10-11]. Additionally, the high trace metals concentrations in the three fish species could also be deduced due to the consumption of phytoplankton during summer and low assimilation of trace metals from the feed during winter. This phenomenon was in line with the earlier studies [12, 20].

The high trace metals toxicity and bioaccumulation factor (BAF) in *R. sarba* was found to be influenced by the metals bioaccumulation and their large body size as observed by earlier investigators[15,17,20]. However, the low bioaccumulation factor (BAF) in *D. sargus* was possibly attributed to their frequent migratory nature to the coastal region and their affinity to wastewater habitat for food. BAF <1 indicated: (1) the assimilation of Fe in the gills, liver and muscle tissues of the fish for their metabolic activities from the wastewater, (2) low absorption of Pb from the medium by the sampled fish, (3) immune resistance of Pb in these fish compared to resistance of Pb in other aquatic organisms [16,18] and (4) the metals detoxification process in the liver [22]. High BAF in gills and the low BAF in the muscle tissues can be related to the metal complex formation with mucus on the gill lamellae and the residual absorption through the intestinal walls, respectively. Although, trace metals concentrations varied between the gills, liver and muscle tissues of the three species due to their morphological and habitat variations, the major cause of trace metals bioaccumulation was attributed due to the perturbed marine ecosystem of Kuwait [14, 19, 21, 26]. Site-wise studies indicating the high trace metals BAF in the fish reared in SVI drain outfalls wastewater attributes to the influence of oil and industrial effluent discharges.

Conclusion

Explicitly, this study validated the angle, distance and the intensity of trace metals concentrations in wastewater dispersed from the drain outfalls and, in line with the site-wise and seasonal variations using the DESCAR-3.2 program. Toxicity and bioaccumulation factor (BAF) in the sampled fish was>1 but, showed no detrimental effects due to the adaptation and migration of these fish in the contaminated wastewater and clean waters, respectively. However, this study indicates a voluminous amount of wastewater discharged from the drain outfalls and hence, a proper treatment of wastewater is suggested before it is let out into the sea.

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Author Contributions

Mr Nabil, contributed the sample collection and analysis in the ICP-MS. Prof. Bu-Olayan, outlaid the governance of the research activities and facilitated the financial and technical support through KFAS and Research Administration, Kuwait University. Dr. Thomas involved in the entire monitoring of the research that included the inception, implementation of research objectives, data and manuscript processes.

Abbreviations

BAF: bioaccumulation factor
TL: total length of fish
L: Linnaeus (fish named after the author)
ICP-MS: Inductively Coupled Plasma-Mass Spectroscopy
DORM-4: fish protein certified reference material
USEPA: US Environmental Protection Authority

References

[1] Vaselali A. and Vaselali M. (2009) *Journal of Applied Sciences*, 9, 3454-3468.

[2] Panigrahi J.K. and Tripathy J.K. (2011) *Applied Ecology & Environmental Research,* 9 (4), 341-354. doi.org/10.15666/aeer

[3] Santschi P.H., Wen L.S. and Guo L. (2001) *Marine Chemistry*, 73 (2), 153–171. Doi.org/10.1016/S0304-4203(00)00102-X.

[4] Robert P.J.W. and Tian X. (2003) *Environmental Modeling & Software,* 19 (7-8),691-699. Doi.org/10.1016/j.envsoft.2003.08.005

[5] Swain J., Umesh P.A., Panigrahi J.K. and Balchand A.N. (2013) *International Journal of Oceans & Oceanography,* 7 (1), 33-46. ISSN 0973-2667

[6] [6] Hu B., Li G., Li J., Bi J., Zhao J. and Bu R. (2013) *Environmental Science & Pollution Research,* 20 (6), 4099-4110. Doi10.1007/s11356-012-1332-z

[7] Yongmin Q., Yang Y., Jiguang Gu. and Zhao J. (2013) *Marine Pollution Bulletin*, 68 (1-2), 140-146. Doi:10.1016/j.marpolbul.2012.12.003

[8] El-MoselhyKh.M., Othman A.I., AbdEl-Azema H. and El-Metwally M.E.A. (2014) *Egyptian Journal of Basic & Applied Sciences,* 1 (2), 97-105. Doi:10.1016/j.ejbas.2014.06.001

[9] Costa P.M., Repolho T., Caeiro S., Diniz M.E., Moura I. andCosta M.H. (2008)*Ecotoxicology & Environment Safety*, 71 (1), 117-124. Doi: 10.1016/j.ecoenv.2007.05.012.

[10] Ghedira J., Jebali J., Bouraoui Z., Banni M., Guerbej H. and Boussetta H. (2010) *Fish Physiology &Biochemistry,* 36 (1),101-107. Doi:10.1007/s10695-008-9295-1

[11] Sarayut O., Caihuan K., Xinhong W., Ke-Jian W. andWen-Xiong W. (2010) *Environmental Pollution*, 158 (5), 1334-1342. Doi:10.1016/j.envpol.2010.01.012

[12] Frias E.M.G., Isidro O.L.J., Martha A.J.V., Daniel C.B., Muy-Rangel M.D., Rubio-Carrasco W., Gabriel L.L., Izaguirre F.G. & Domenico V. (2011) *Environmental Monitoring & Assessment,* 182 (1-4),133-139. Doi:10.1007/s10661-010-1864-y

[13] FAO-FIES (Food and Agriculture Organization-Food Insecurity Experience Scale, Aquatic Sciences and Fisheries Information System (ASFIS) species list, (2012) http://www.fao.org/fishery/collection/asfis/en. Accessed March 2012.

[14] Abdel-Moati M.A.R. and Nasir N.A. (1997)*Qatar University Science Journal,* 17 (1), 195-203.http://hdl.handle.net/10576/10146

[15] Gillanders B.M. and Kingsford M.J. (2003) *Estuarine Coastal & Shelf Fish Science*, 57(5-6), 1049-1064. Doi:10.1016/S0272-7714(03)00009-X

[16] Carvalho M.L., Santiago S. and Nunes, M.L. (2005) *Analytical & Bio-Analytical Chemistry,* 382 (2): 426-432. Doi:10.1007/s00216-004-3005-3.

[17] Wang W.X. and Rainbow P.S. (2008) *Comparative Biochemistry &* Physiology-*Part C: Toxicology & Pharmacology,* 148 (4), 315-323. Doi:10.1016/j.cbpc.2008.04.003

[18] Creti P., Trinchella F. and Scudiero R. (2010) *Environmental Monitoring & Assessment,* 165 (1-4), 321-329. Doi:10.1007/s10661-009-0948-z

[19] Uysal K. and Emre Y. (2011) *Anadolu University Journal of Science and Technology-CLife Sciences & Biotechnology,* 1 (1),95-102.

[20] El-MoselhyKh M. and El-Boray K.F. (2004) *Egyptian Journal of Aquatic Biology & Fisheries,* 8 (2), 59-78.

[21] Dang F, Wen-Xiong W. and Rainbow P.S. (2012) *Environmental Science & Technology*, 46 (6), 3465-3471. Doi: 10.1021/es203951z

[22] Yabanli M., Alparslan Y. and Baygar T. (2012) *Agricultural Sciences*, 3 (5), 669-673. Doi: 10.4236/as.2012.35081

[23] APHA (American Public Health Association) (2012) *Standard Methods for the examination of water and wastewater.* 22th edition, Water Environmental Federation Joint Publishers, 1015 fifteenth street, NW, Washington, DC,USA, pp.1496. ISBN: 9780875530139

[24] Jirka G.H. (2004) *Environmental Fluid Mechanics.* Kluwer Academic Publishers, Netherlands, pp.1-56.

[25] USEPA. (1993) Statistical Analysis for Biological Methods. http://www.epa.gov/nerleerd/stat2.htm#probit,1

[26] Patrice C. and Greg P. (2011) *Fish Physiology*, 31 A, 417–473. Doi.org/10.1016/S1546-5098 (11)31009-6