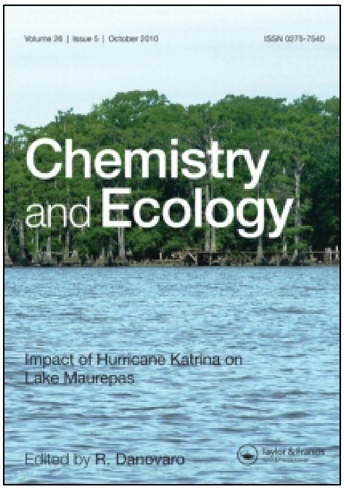

Chemistry and Ecology
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713455114

The Relationship Between Iodine, Chlorinity, Ph, Reactive Phosphate, Nitrite and Organic Matter in the Coastal Water of Alexandria

Thanaa H. Mahmoud[a]; Mohamed El Deek[a]
[a] National Institute of Oceanography and Fisheries, Alexandria, Egypt

To cite this Article Mahmoud, Thanaa H. and Deek, Mohamed El(1997) 'The Relationship Between Iodine, Chlorinity, Ph, Reactive Phosphate, Nitrite and Organic Matter in the Coastal Water of Alexandria', Chemistry and Ecology, 14: 1, 39 — 54
To link to this Article: DOI: 10.1080/02757549708035538
URL: http://dx.doi.org/10.1080/02757549708035538

Chemistry and Ecology, 1997, Vol. 14, pp. 39-54
Reprints available directly from the publisher
Photocopying permitted by license only

THE RELATIONSHIP BETWEEN IODINE, CHLORINITY, pH, REACTIVE PHOSPHATE, NITRITE AND ORGANIC MATTER IN THE COASTAL WATER OF ALEXANDRIA

THANAA H. MAHMOUD and MOHAMED S. EL DEEK

National Institute of Oceanography and Fisheries,
Kayet Bey, Alexandria, Egypt

(Received 7 March 1997; Revised 20 May 1997)

Water samples were taken from 12 stations at El-Dikheila Harbour, El-Mex Bay, Western Harbour, Qayet Bey outfall, Eastern Harbour, El-Ibrahemiya, Gleem, Sidi Bishr and Mandara, during January, April, August and November 1995. The area lies between latitude 31° 8' and 31° 17' North and longitude 29° 47' and 30° East. The annual mean of chlorinity (11.69–20.5‰), pH (7.9–8.3), reactive phosphate (0.31–2.24 μM), nitrite (0.18–1.98 μM), oxidizable organic matter (1.97–8.95 $mgO_2\ l^{-1}$), iodide (21.14–46.74 $\mu g\ l^{-1}$) and iodate (4.61–2.04 $\mu g\ l^{-1}$) were measured. Iodide content in water is three times higher than iodate. Iodide is positively correlated with chlorinity ($r = 0.65$) and iodate ($r = 0.45$), while it is negatively correlated with nitrite ($r = -0.72$), oxidizable organic matter ($r = -0.55$) and pH ($r = -0.4$).

Keywords: Iodide; iodate; chlorinity; pH; reactive phosphate; nitrite; oxidizable organic matter; coastal water

INTRODUCTION

During the last two decades, the Mediterranean coast of Egypt has witnessed significant expansion. An increasing number of industries has been built up and considerable technological developments have occurred. The major type of pollution sources are domestic sewage outfalls, industrial wastes and agricultural run off through lake outlets, river discharges and oil pollution. The studied area is located between El-Dikheila Harbour in El-Mex Bay and Mandara between longitude 29° 47' and 30° 00' East and latitude 31° 8' and 31° 17 North. El-Mex bay (site 1) receives a heavy load of waste water both directly from industrial outfalls and indirectly from Lake Maryut through the El-Umum drain. The drain discharges about 2.4×10^9 m^3 annually, while on the other hand Qayet Bey (site VI), Eastern Harbour (site VII), El-Ibrahimiya (site IX), Gleem (site X), Sidi Bishr (site XI) and Mandara (site XII) areas are affected by the discharge of sewage from the main sewer outfall, which discharge about 57×10^6 m^3 annually and also from some smaller outfalls located on the coast of these areas.

Iodine is a very important in the human daily diet, so it is recommended that the adult intake of iodine should be 150 μg day^{-1} (Martin and Flick, 1985; Borgstrom, 1962). This recommended dietary allowance is not difficult to meet if sea foods are included in the diet and provides the thyroxine for iodine use. The iodine values for fish range from 16 to 318 μg/100g of flesh, and the population near the sea receive more iodine than those further inland. Japan has no goitre conditions as in other countries because of its proximity to the ocean and the sea foods in their diets (Borgstrom, 1962). Iodine is which has been shown essential to plants and produces a stimulating effect on growth at low concentrations. Toxic effects are produced at higher concentrations, and iodide toxicity has been found where the level in a marine plant is an excess of 8 ppm. Normal level in healthy plants range from 0–0.5 ppm, (Martin and Flick, 1985; Borgstrom, 1962)

Iodine in sea water has been the subject of numerous investigations inspired by biological and geochemical importance of the element. The speciation and biogeochemical cycling of iodine in the oceans has been under extensive investigation in recent years. Dissolved iodine exists in two major forms of oxidation states, iodide (I^-) and iodate (I^{5+}) (Tsunogai, 1971; Herring and Liss, 1974; Wong, 1977; Elderfield and Truesdale, 1980; Luther *et al.*, 1988; Ullman *et al.*, 1990). The occurrence of organically bound iodine in sea water samples has been verified by Lovelock *et al.* (1973) and Truesdale (1975). Iodate is a thermodynamically stable form of iodine in sea water at pH 8.1. The ratio of iodate to iodine (I^{5+}/I^{-1}) is typically 5–10 in surface ocean waters where biological processes are important. The ratio varies with geographical location and with depth. The total iodine content of sea water (approximately 50–60 μg l^{-1}) is believed to be composed of iodate (30–60 μg l^{-1}) and iodide (0.0–20 μg l^{-1}), with perhaps a few μg l^{-1} of organically bound iodine (Truesdale, 1978). Total iodine and iodate show relative maxima in concentration at the oxygen minimum zone analogous to those for the nutrient elements, nitrogen and phosphorus (Wong and Brewer, 1974; Wong, 1977; Ullman *et al.*, 1990).

The objective of this study is to determine iodine speciation and behaviour, and its correlation with chlorinity, hydrogen ion concentrations, reactive phosphate, nitrite, and oxidizable organic matter in the study area Since this is the first time to measure iodine species in the coastal water of Alexandria, this study is considered as a pilot study but El Deek *et al.* (1994) studied the iodine cycling in the Suez Bay.

MATERIAL AND METHODS

Water samples were taken from the surface water in a plastic sampling bottle and from bottom water in a Nansen bottle. They were collected from 12 stations (from I to XII) in January, April, August and November, 1995. These stations are located in front of El-Dikheila Harbour (site III), El-Mex Bay (sites I, II, IV), Western Harbour (site V and VI), Qayet Bey outfall (site VII), Eastern Harbour (site VIII), El-Ibrahemiya (site IX), Gleem (site X), Sidi Bishr (site XI) and Mandara (site XII). The area lies between longitude 29° 47′ and 30° East and latitude 31° 8′ and 31° 17′ North (Fig. 1). Salinity was measured by Beckman salinometer and then chlorinity values were calculated by using equation:

$$\text{Salinity } (\text{‰}) = 0.03 + 1.805 \text{ (Chlorinity ‰)}.$$

Hydrogen ion concentration (pH) was measured by a portable digital pH meter from Orion research, model 210. Reactive phosphate and nitrite samples were measured by using spectrophotometer Shimadzu double beam, according to methods described by Grasshoff (1983). The oxidizable organic matter was determined according to Ellis *et al.* (1946). Iodate, which is the oxidized form of iodine, was determined by using the method of Jickells *et al.* (1988); the iodine species of interest are first converted to iodate, then the iodate is reacted with acid and excess of iodide to give iodonium ion, I^3, which

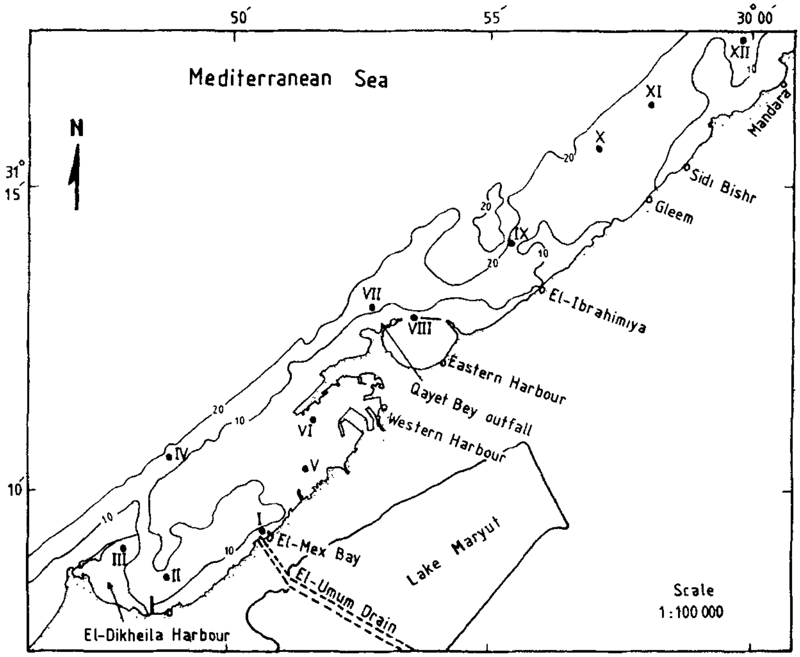

FIGURE 1 Position of sampling stations in the area investigated.

is detected by photometry out of direct sunlight (at 350 nm), while iodide was determined by using the method of Rogina and Dubravcic (1953). The method is based on the catalytic effect of iodides on the reduction of ceric ammonium sulphate by arsenious acid. The rate of the reduction is readily determined by arresting the reaction at a given time by the addition of ferrous and thiocyanate solution and by measuring the resulting red colour of ferric thiocyanate by means of a photometer (at 540 nm).

RESULTS AND DISCUSSION

Chlorinity

It is observed that surface waters have lower chlorinity values than the bottom water *i. e.* the general trend of the vertical distribution of chlorinity is an increase with depth during the period of investigation. The regional average chlorinity values ranged from 11.69 ± 0.97‰ at site II to 20.51 ± 1.27‰ at site XII in the surface and from 19.50 ± 1.88‰ at site XI to 20.79 ± 1.17‰ at site X in the bottom water (Fig. 2b). The monthly average chlorinity values fluctuated between 16.63 ± 2.41‰ in August and 17.97 ± 4.31‰ in April in the surface and between 19.42 ± 0.36‰ in November and 21.78 ± 0.29‰ in April in bottom water (Fig. 3). High chlorinity values in the bottom water layers can be related to the sinking of the denser, more chlorinity, water which was first formed near the surface due to water evaporation. The sewage wastes and brackish water discharge to the area decreased surface chlorinity, and decrease in chlorinity values is attributed

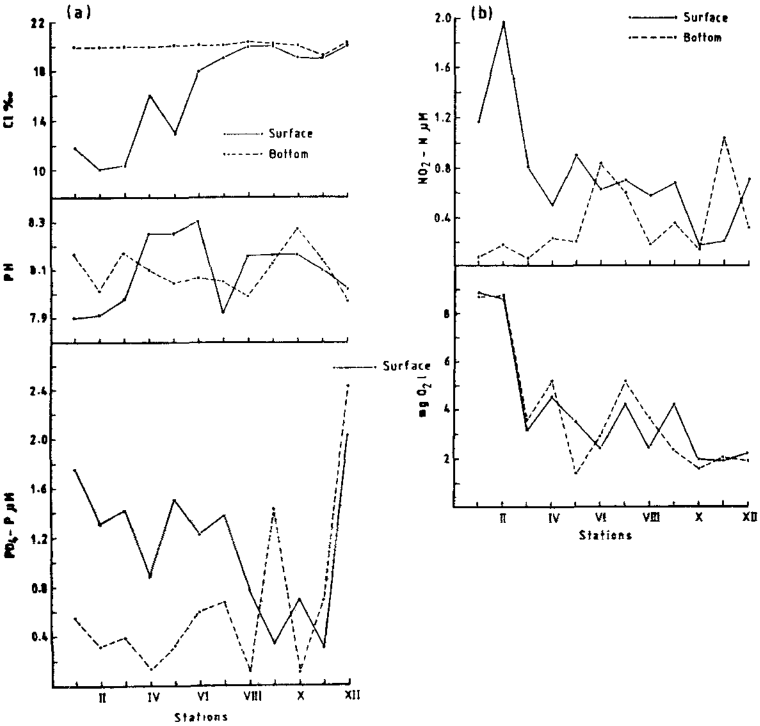

FIGURE 2 (a, b) Variations of the average values of chlorinity (Cl‰), pH, reactive phosphate (µM), nitrite (µM) and oxidizable organic matter ($mg\,O_2\,l^{-1}$) at different stations in the investigated area during January–November 1995.

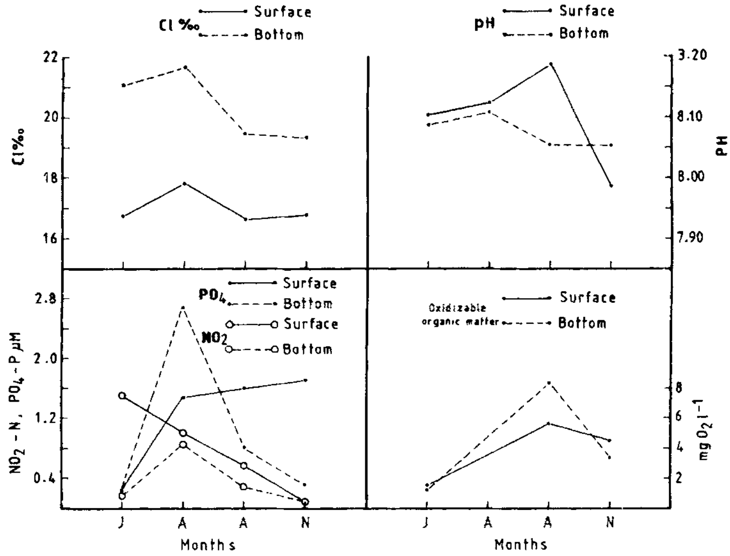

FIGURE 3 Variations of the monthly average values of chlorinity (Cl‰), pH, reactive phosphate (μM), nitrite (μM) and oxidizable organic matter (mg O_2 l^{-1}) in the investigated area during January–November 1995.

to diluting agencies rather than to natural factors. The annual average value of chlorinity in the investigated area in the surface (17.06 ± 0.53 ‰) is lower than in the bottom (20.46 ± 1.04 ‰).

Hydrogen Ion Concentration (pH)

In most months, the values of pH increased with depth at some stations. However, a decrease with depth occurred during many months and in many stations. Irregularity in the vertical pH values was observed in the majority of months at some stations. The average pH values showed generally slight local variations. Regional average value is very high at site VI (8.3 ± 0.06) and very low at site I (7.92 ± 0.11) at surface water and ranged between 7.97 ± 0.03 at site XII and 8.27 ± 0.31 at site X at the bottom water (Fig. 2a). The monthly average surface values of pH fluctuated between 7.99 ± 0.12 in November and 8.19 ± 0.23 in August, while at bottom water it ranged between 8.05 ± 0.10 in November and 8.11 ± 0.03 in April (Fig. 3). The pH of the coastal water of Alexandria is influenced by many factors, principally water temperature, photosynthetic activity, dissolved oxygen and the waste water discharged to the area. The decrease in pH values in the bottom water coincided with the decomposition of the descending plankton and organic matter in the water and sediments. The maximum monthly average pH value which is found in August may be due to increase in the rate of photosynthetic activity which raises the pH as a result of the consumption of carbon dioxide and subsequent increase in oxygen concentration in the water.

Reactive Phosphate

The regional average values of reactive phosphate fluctuate between 0.31 ± 0.2 μM at site XI and 2.24 ± 2.6 μM at site XII at surface water, while its concentrations at the bottom water ranged between 0.12 ± 0.04 μM and 2.44 ± 2.21 μM at sites XII and VIII (Fig. 2a). The values of reactive phosphate showed a decrease with depth in all stations except at sites IX, XI, XII. The monthly average variation of phosphates showed that the highest content is found in November (1.75 ± 1.94 μM) at the surface water and in April at the bottom water (2.72 ± 2.09 μM). Its lowest content is found in January at both surface and bottom water (0.25 ± 0.11 μM and 0.22 ± 0.14 μM). Phosphate content at different months at surface water is higher than at the bottom (Fig. 3) except in April; this may be attributed to increasing the quantity of phytoplankton in this month causing an increase in the uptake rate of phosphate.

Nitrite

A decrease of a nitrite content with depth was noted in several months at most stations except at sites VI and XI (Fig. 2b). Surface nitrite concentrations fluctuated between 0.18 ± 0.08 μM at site X and 1.98 ± 1.64 μM at site II, while at the bottom water maximum nitrite content is found at site XI (1.02 ± 1.07 μM) and a minimum at site III (0.08 ± 0.04 μM). Monthly variations of nitrite content in the investigated area showed that its values at the surface is higher than that at the bottom at all months (Fig. 3). Nitrite content ranged between

$0.13 \pm 0.06\,\mu M$ in November and $1.00 \pm 0.83\ \mu M$ in January at the surface and from $0.14 \pm 0.26\,\mu M$ in November to $0.87 \pm 1.11\,\mu M$ in April at the bottom. The increase in nitrite content in the surface water and its decrease with depth noticed in several months at some stations are due to the production of nitrite as an intermediate step in the oxidation of organic nitrogen through ammonia to nitrate as well as the oxidation of ammonia and secretion from marine phytoplankton. It is also attributed to the effect of waste water discharged to the area.

The Oxidizable Organic Matter

Domestic sewage, agricultural run off and industrial wastes introduce large amounts of organic substances into the coastal water of Alexandria. Regional average values fluctuated between $1.97 \pm 0.82\ mgO_2l^{-1}$ at site XI and $8.95 \pm 0.46\ mgO_2l^{-1}$ at site I at surface water. In bottom water site I has also the highest content of oxidizable organic matter $9.85 \pm 11.99\ mgO_2l^{-1}$ and site V has the lowest content $1.36 \pm 0.84\ mgO_2l^{-1}$. Site I has the highest content in both surface and bottom water because its site is just near to the El Umum Drain. Bottom water has higher concentrations of oxidizable organic matter than surface water except at sites I, V, IX, X and XII (Fig. 2b). On the other hand, monthly variation indicates that its concentration at surface water in January and November is higher than in bottom water. Monthly variation of oxidizable organic matter showed that August had the highest concentrations (Fig. 3) in both surface and bottom water layers (5.77 ± 5.19 and $8.44 \pm 9.63\ mgO_2l^{-1}$), while January has the lowest value ($1.82 \pm 0.93\ mgO_2l^{-1}$). Maximum content of oxidizable organic matter is related to increase in the quantity of plankton during this month.

The annual mean of phosphate, nitrite and pH in the surface water of the investigated area are higher than their content in the bottom water ($1.28 \pm 0.6\,\mu M$, $0.82 \pm 0.5\,\mu M$ and 8.10 ± 0.08 in the surface respectively, $1.04 \pm 1.0\,\mu M$, $0.40 \pm 0.28\,\mu M$ and 8.08 ± 0.02 in the bottom, respectively). On the other hand, chlorinity and oxidizable organic matter values in the surface (17.06 ± 0.53‰ and $4.08 \pm 1.66\ mgO_2l^{-1}$) are lower than their values in the bottom (20.46 ± 1.04‰ and $4.52 \pm 2.89\ mgO_2l^{-1}$). This may indicate their allochthonous origin, since they may be discharged to the area from El-Umum Drain and the sewage outfalls located along the coast.

Iodide

Iodine is maintained principally in its reduced state (I^-). This occurs by two processes, first exchange across the pycnocline into anoxic water would ensure that any iodate, if formed, would be reduced by sulphide to iodide. Secondary biological process in the surface waters may maintain iodine as iodide for ready uptake since iodide is the more important form of iodine to organisms. Both of these processes coupled with slow chemical conversion of iodide to iodate should maintain iodine in its reduced state (Luther and Cole, 1988).

The dominant iodine species through the water column in the investigated area is iodide, where it is 3 times higher than iodate. In surface water, iodide is present at levels up to $41.51 \pm 19.33\,\mu g\,l^{-1}$ at site VII, decreased to $13.29 \pm 4.68\,\mu g\,l^{-1}$ at site II, but this concentration increased in the bottom water up to $42.17 \pm 26.42\,\mu g\,l^{-1}$ at site VI and $24.12 \pm 19.62\,\mu g\,l^{-1}$ at site XII. Surface water contains iodide lower than bottom water except at sites III, IX, X, XI and XII (Fig. 4). This increase in the iodide values at bottom water rather than at surface water may be related to the continuous reduction of iodate during the decomposition of phytoplankton (Elderfield and Truesdale, 1980), microbiological reduction (Tsunogai and Henmi, 1971) and the enzymatic reduction of iodate by nitrate reductase (Calvert and Price, 1971). It may be also due to a possible flux of iodide from the bottom sediments (Tsunogai, 1971) and aerobic organisms could also reduce to iodate (Truesdale and Smith, 1975). Monthly variations of iodide (Fig. 5) indicates that April has the highest iodide content $46.74 \pm 14.32\,\mu g\,l^{-1}$, while August and November have the lowest measurements at the surface water $21.14 \pm 77\,\mu g\,l^{-1}$ and $21.20 \pm 5.40\,\mu g\,l^{-1}$. The increase in iodide concentrations in summer (August) is accompanied by an increase in some other parameters as temperature (29.77 ± 0.57°C), chlorinity (17.97 ± 4.31‰), reactive phosphate $1.52 \pm 1.29\,\mu M$. The increase in iodide content may be bacterially mediated remineralization of dissolved or particulate organic phase, direct chemical reduction of iodate, reduction or displacement of iodine adsorbed on organic particles and nucleophilic displacement of iodine

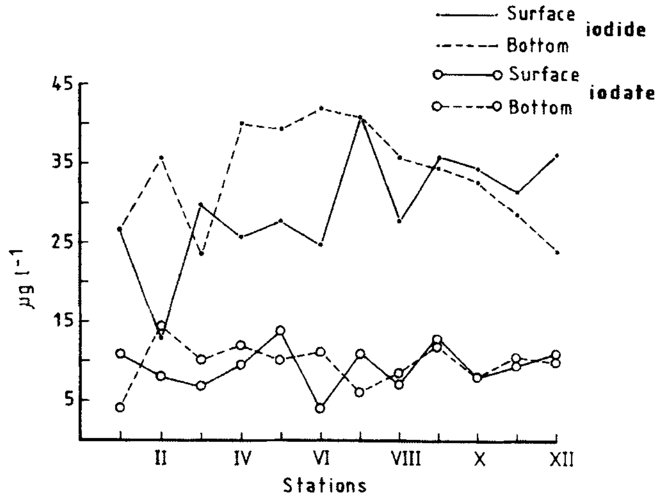

FIGURE 4 Variations of the average values of iodide and iodate ($\mu g\,l^{-1}$) in the investigated area at different sites during January – November 1995.

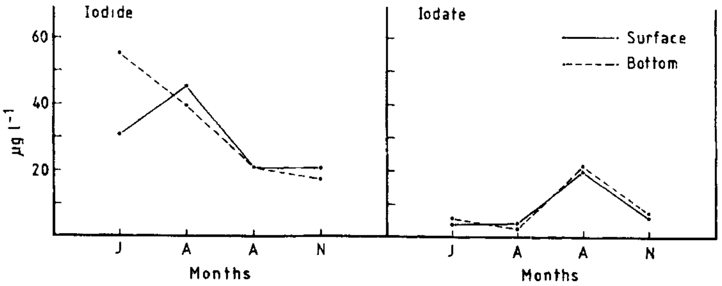

FIGURE 5 Variations of the monthly average values of iodide and iodate ($\mu g\,l^{-1}$) in the investigated area during January – November 1995.

in organic phase with other species produced in the water column. The presence of small amounts of iodide in the oxic water column indicates either that iodide is much more persistent in oxygenated waters than thought before, or that it is being produced at or near the depths where it is observed (Ullman *et al.*, 1990).

Iodide is in constant ratio to chlorinity except in regions where phytoplankton and particularly the larger benthic algae are active and when differential biological concentration can modify iodide/chlorinity ratio significantly so that biological activity can account for the observed variation in iodine/chlorinity ratio at depths of 200m (Richard and Thomspon, 1960). Iodide/chlorinity ratio in the investigated area is not constant at all depths and locations due to the presence of the great amount of phytoplankton. The ratio fluctuated between 2.25 at site III and 1.14 at site II in the surface water and between 2.08 at site VI and 1.16 at site XII in the bottom water (Table I). The annual mean of iodide/chlorinity ratio is highest in the surface, 1.78 ± 0.33, and low in the bottom water, 1.67 ± 0.3. This low bottom value are related to increase in the bottom chlorinity values.

The annual mean of iodide in the surface water is lower than in the bottom water ($30.25 \pm 10.48\,\mu g l^{-1}$ and $34.22 \pm 15.1\,\mu g l^{-1}$). Low surface values are attributed to biological processes in the surface water may maintain iodide for ready uptake, since iodide is the more important form of iodine to organisms. It may be also due to the reduction of iodine by sulphide which is present in waste water discharged to the area, and slow chemical conversion of iodide to iodate. Low iodide content in the surface water of the investigated area coincides with low chlorinity (17.06 ± 0.53 ‰) and oxidizable organic

TABLE I Iodide, iodate, chlorinity ratio in the investigated area

Stations		*Iodide-chlorinity ratio*	*Iodate-chlorinity ratio*	*Stations*		*Iodide-chlorinity ratio*	*Iodate-chlorinity ratio*
I	S	2.223	1.019	S	VII	2.171	0.590
	B	1.341	0.210	B		2.016	0.294
II	S	1.135	0.717	S	VIII	1.465	0.396
	B	1.732	0.678	B		1.747	0.415
III	S	2.253	0.530	S	IX	1.826	0.668
	B	1.214	0.509	B		1.706	0.603
IV	S	1.616	0.562	S	X	1.763	0.448
	B	1.980	0.623	B		1.605	0.385
V	S	2.045	1.085	S	XI	1.684	0.492
	B	1.945	0.521	B		1.505	0.548
VI	S	1.430	0.274	S	XII	1.799	0.539
	B	2.080	0.577	B		1.161	0.487
Regional	S	1.784 ± 0.33		S			0.610 ± 0.227
mean	B	1.670 ± 0.30		B			0.488 ± 0.133

S = Surface
B = Bottom

matter (4.07 ± 1.66 mgO$_2$l^{-1}) and high pH (8.10 ± 0.07), reactive phosphate (1.28 ± 0.60 μM) and nitrite (0.82 ± 0.51 μM).

Iodate

Iodate content in the coastal water is very low. Regional means fluctuated between 4.97 ± 1.38 μg l^{-1} at site VI and 14.98 ± 18.60 μg l^{-1} at site V in the surface water, while in bottom water, it was between 4.31 ± 1.43 μg l^{-1} at site I and 14.03 ± 12.51 μg l^{-1} at site II (Fig. 4). Monthly variation of iodates (Fig. 5) indicated that maximum iodate surface value is found in August at both surface (20.40 ± 12.29 μg l^{-1}) and bottom water (22.62 ± 9.93 μg l^{-1}), and the minimum value is in April at both surface (4.61 ± 1.70 μg l^{-1}) and bottom water (4.18 ± 1.56 μg l^{-1}). High iodate content in August coincides with low iodide content, but may related to the oxidation of iodide to iodate due to increase in temperature, organic matter, low reactive phosphate and nitrite. It may be increased in the quantity of phytoplankton which uses iodide as a source of nutrients or may be attributed to decrease in the chemical rate of conversion of iodate to iodide, or may be due to the reduction of iodate as a result of increasing of oxidizable organic matter from waste water discharged. Truesdale (1974) found that the oxidation or iodination of organic matter dissolved in sea water provides us with iodide or iodate.

Iodate/chlorinity ratio in the surface water (0.61 ± 0.23) is higher than in the bottom water (0.49 ± 0.13).

Generally, surface and bottom water iodide content were found to be higher than of iodate in the coastal water. It is clear that the reduction process exerts far greater effect on molecular iodine than the disproportion reaction which gives as an evident pollution effect. This is the major reason leading the reaction to process in the way, and the interconversion of iodide and iodate is represented by the equation:

$$IO_3^- + 6H + 6e^- \rightleftharpoons I^- + 3H_2O$$

Thus, the production of iodide plays an important role in the cycle of iodine in the area. The knowledge of the forms of iodine can be used as a chemical marker for geological and/or physical features in our investigated area, and it can also be used for the determination of water quality.

The correlation coefficients and regression equations between iodide, iodate, chlorinity, nitrite, reactive phosphate, oxidizable organic matter and pH were calculated in January, April, August and November (1995) using a computer program STATGRAPHICS (statistical graphic system, 1987, Version 2.6). When the number of samples is equal to 24, the correlation coefficients value is significant when they are equal to, or more than, 0.3089. There were no correlations between these variables in April. In January, where iodide was significantly correlated with chlorinity ($r = 0.65$) and nitrite ($r = 0.72$). Luther and Cole (1988) found that total iodine (sum of iodate and iodide) increases linearly with salinity ($r = 0.98$) and thus appear to be conservative with salinity. They also found that iodides are positively correlated with salinity, with above salinity 21‰, iodide is negatively correlated with salinity.

In August, iodide is significantly correlated with iodate ($r = 0.45$) and organic matter ($r = 0.55$). This negative correlation indicates that when oxidizable organic matter content increases, iodide content decreases either due to its consumption by phytoplankton or its oxidation by organic matter.

In November, iodide is negatively correlated with pH ($r = -0.4$). This is attributed to the fact that when pH increases due to increase in the quantity of plankton, iodide content decreases because it consumed by them.

Comparing data for the measured variables in the present study and in other studies in different areas are tabulated in Table II. It can be seen that chlorinity and pH values ranged between 10.32 to 24.47‰ and 7.50 to 8.35‰ in Abu Qir Bay, El Mex Bay, Eastern and Western Harbours and Kayet Bey areas are in the same range of the present study (11.69–20.5 and 7.9–8.3). Reactive phosphate (0.0–35.9 μM), nitrite (0.00–21.6 μM) and oxidizable organic matter (0.13–16.24 $mgO_2 I^{-1}$) content in the previously mentioned areas are higher than in the present study 0.31–2.24 μM, 0.18–1.98 μM and 1.97–8.95 $mgO_2 I^{-1}$, respectively. This may be attributed to decrease in their dissolved amounts in the waste water discharged to the studied area.

If data for iodide in the present study are compared with data from Suez Bay and Chesapeake Bay, we found that the Suez Bay has the

TABLE II Concentrations of chlorinity (‰), pH, reactive phosphate (P-PO$_4$ μM), nitrite (N-NO$_2$ μM), oxidizable organic matter (mg O$_2$ l^{-1}), iodide and iodate (μg l^{-1}), reported from the same area and from the present study included for comparison

Eco system	*Chlorinity*	*pH*	*PO$_4$-P*	*NO$_2$-N*	*Oxidizable organic matter*	*Iodide*	*Iodate*	*References*
Abu Qir Bay	–	–	0.82–1.94	4.98–15.43	–	–	–	Mahmoud and Abel Hameid (1991)
Abu Qir Bay	10.32–22.12	–	–	–	–	–	–	Tayel and Shriadah (1992)
Coastal water of Alexandria	–	7.96–8.15	0.22–17.73	0.09–1.62	–	–	–	Mahmoud (1995)
Eastern Harbour	15.22–21.26	–	–	–	–	–	–	Shriadah and Emara (1992)
Eastern Harbour	–	–	0.44–17.6	0.0–4.68	0.4–13.8	–	–	Emara *et al.* (1992)
El-Mex Bay	18.85–21.55	–	–	–	–	–	–	Shriadah and Emara (1992)
El-Mex Bay	–	–	0.35–9.37	0.32–21.6	0.13–9.94	–	–	Emara *et al.* (1992)
El-Mex Bay	–	7.5–8.35	0.55–9.26	0.41–17.24	0.95–9.94	–	–	Said *et al.* (1994)
El-Mex Bay	–	7.85–8.0	0.0–35.9	–	5.17–13.6	–	–	Mahmoud (1986)
Kayet Bay	–	7.5–8.2	0.10–0.89	–	1.47–16.24	–	–	Mahmoud (1986)
Western Harbour	–	7.7–8.25	0.003–2.21	0.22–2.84	0.36–13.60	–	–	Shriadah and Tayel (1992)
Western Harbour	13.81–24.47	–	–	–	–	–	–	Shriadah (1992)
Suez Bay	–	–	–	–	–	38.43–46.38	7.23–10.79	El Deek *et al.* (1994)
Chesapeake Bay	–	–	–	–	–	8.12–45.94	0.0–28.81	Luther and Cole (1988)
Studied area	11.69–20.51	7.9–8.3	0.31–2.24	0.18–1.98	1.97–8.95	21.14–46.74	4.61–20.4	Present study

highest iodide content 38.43–46.38 $\mu g l^{-1}$, while in the present study 21.14–46.74 $\mu g l^{-1}$ and Chesapeake Bay 8.12–45.94 $\mu g l^{-1}$ are almost have the same contents. It is also observed that iodide content at the previously mentioned areas are higher than iodate content; this indicates that these areas are reducible environments. Iodate content in the present stduy (4.61–20.4 $\mu g l^{-1}$) is higher than in the Suez Bay (7.23–10.79 $\mu g l^{-1}$) and Chesapeake Bay (0.0–28.81 $\mu g l^{-1}$).

References

Borgstrom, G. (1962) Nutrition, sanitation and utilization with contribution, *Journal Fish as Food*, **2**, 214–227.

Calvert, S. E. and Price, N. B. (1971) Upwelling and nutrient regeneration in the Benguela current, *Deep-Sea Research*, **18**, 505–523.

El-Deek, M. S., Youssef, M. A. and Mohamed, A. A. (1994) Iodine cycling in the Suez Bay. *Proceeding of the 4th International Conference for Environmental Studies and Research. Towards a Better Environment. Institute of Environmental studies and Research, Ain-Shams University, Cairo*, pp. 172–183.

Elderfield, H. and Truesdale, V. W. (1980) On the biophilic nature of iodine in seawater. *Earth and Planetary Science Letters*, **50**, 105–114.

Ellis, M. M., Westafall, B. A. and Ellis, D. M. (1946) Determination of water quality. *U. S. Department International Fish and Wildlife Service, Research Report No.*, **9**, 122 pp.

Emara, H., Shriadah, M. A., Mahmoud, Th. H. and El-Deek, M. S. (1992) The effect of sewage and industrial wastes on the chemical characteristics of the Eastern Harbour and El-Mex Bay waters of Alexandria, Egypt. *Proceedings of an International Conference in Marine Coastal Eutrophication, Bologna, Italy*, 21–24 March, 1990, *Science Total Environment*, Special Volume, pp. 773–784.

Grasshoff, K. (1983) *Methods of Sea Water Analysis*, Second Edition, Verlage, Chemie, New York, pp. 317.

Herring, J. R. and Liss, P. S. (1974) A new method for the determination of iodine species in seawater. *Deep-Sea Research*, **21**, 777–783.

Jickells, T. D., Boyd, S. S. and Knap, A. H. (1988) Iodine cycling in the Sargasso Sea and the Bermuda inshore waters. *Marine Chemistry*, **24**, 61–82.

Lovelock, J. E., Maggs, R. J. and Wade, R. J. (1973) Halogenated hydrocarbon in and over the Atlantic. *Nature* (London), **241**; 194–196.

Luther, G. W. and Cole, H. (1988) Iodine speciation in Chesapeake Bay waters. *Marine Chemistry*, **24**, 315–325.

Luther, G. W., Swartz, C. B. and Ullman, W. J. (1988) Direct determination of iodide in sea water by cathodic stripping square wave voltammetry. *Analytical Chemistry*, **60**, 1721–1724.

Mahmoud, Th. H. (1986) Phosphorus and nitrogen dynamics in the polluted coastal waters off Alexandria. *Ph. D. Thesis*, Alexandria University, pp. 301.

Mahmoud, Th. H. (1995) The effect of sewage discharge on water quality off the coast of Alexandria in spring and summer. *Chemistry and Ecology*, **11**, 1–14.

Mahmoud, Th. H. and Abdel Hamied, O. H. (1991) The distribution and relationship between nitrogen and phosphorus compounds in Abu Qir Bay, Alexandria Egypt. *Bulletin of the High Institute of Public Health*, **12**, 359–370.

Martin, R. E. and Flick, G. J. (1985) Nutrition and Preparation. The Seafood Industry, *Van Nostrand Reinhold*. New York, 260–261.

Richard, A. B. and Thompson, T. G. (1960) The total iodine and iodate/iodine content of sea water. *Deep Sea Research*, **7**, 24–34.

Rogina, B. and Dubravcic, M. (1953) Micro-determination of iodide by arresting the catalytic reduction of ceric ions. *Analyst*, **78**, 594–599.

Said, M. A., El-Deek, M. S., Mahmoud, Th. H. and Shriadah, M. A. (1994) Effect of pollution on the hydrochemical characteristics of different water types in El-Mex area, west of Alexandria, Egypt. *Acta Adriatica*, **34(1/2)**, 9–19.

Shriadah, M. A. (1992) Major cations and alkalinity in the sea waters of the Western Harbour, Alexandria. *The Bulletin of the High Institute of Public Health*, **22**, 481–497.

Shriadah, M. A. and Emara, H. I. (1992) Major cations and alkalinity in the Eastern Harbour and El-mex Bay. *Bulletin of the Faculty of Science*, Alexandria University, **32(A)**, 156–174.

Shriadah, M. A. and Tayel, F. T. (1992) Environmental condition of the Western Harbour of Alexandria, 1- Physico-chemical characteristics. *The Bulletin of the High Institute of Public Health*, **22**, 213–230.

Tayel, F. T. and Shriadah, M. A. (1992) The distribution of alkalinity, some major cations and their chlorinity ratio in the sea waters of Abu-Qir Bay. *Bulletin of the Faculty of Science, Alexandria University*, **32(A)**, 176–194.

Truesdale, V. W. (1974) The chemical reduction of molecular iodine in seawater. *Deep Sea Research*, **21**, 761–766.

Truesdale, V. W. (1975) "Reactive" and "unreactive" iodine in seawater- a possible indication of an organically bound iodine fraction. *Marine Chemistry*, **3**, 111–119.

Truesdale, V. W. (1978) Iodine in inshore and offshore marine waters. *Marine Chemistry*, **6**, 1–13.

Truesdale, V. W. and Smith, P. J. (1975) The automatic determination of iodine or iodate in solution by catalytic spectrophotometry, with particular reference to river water. *Analyst*, **100**, 111–123.

Tsunogai, S. (1971) Iodine in the deep water of the oceans . *Deep Sea Research*, **18**, 913–919.

Tsunogai, S. and Henmi, T. (1971) Iodine in the surface water of the ocean. *Journal of the Oceanographical Society of Japan*, **27**, 67–72.

Ullman, W. J., Luther, G. W., De Lange, G. J. and Woittiez, J. R. W. (1990) Iodine chemistry in deep anoxic basins and overlying waters of the Mediterranean Sea. *Marine Chemistry*, **31**, 153–170.

Wong, G. T. F. (1977) The distribution of iodine in the upper layers of the equatorial Atlantic. *Deep Sea Research*, **24**, 115–125.

Wong, G. T. F. and Brewer, P. G. (1974) The determination and distribution of iodate in south Atlantic waters. *Journal Marine Research*, **32**, 25–36.