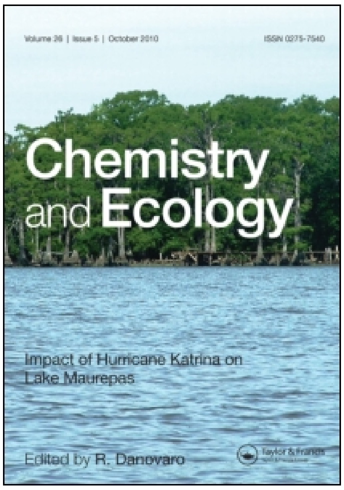

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Trace Metals in Fish and Crustaceans - Identifying Heavier Polluted Areas in the Ghanaian Continental Shelf

David K. Dodoo[a]; Soraya A. Tabbicca[a]; Peter Aryee-Sackey[a]
[a] Environmental Research Group, Department of Chemistry, University of Cape Coast, Ghana

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TRACE METALS IN FISH AND CRUSTACEANS – IDENTIFYING HEAVIER POLLUTED AREAS IN THE GHANAIAN CONTINENTAL SHELF

DAVID K. DODOO*, SORAYA A. TABBICCA
and PETER ARYEE-SACKEY

Environmental Research Group, Department of Chemistry, University of Cape Coast, Ghana

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The concentrations of four trace metals, namely copper, lead, cadmium and manganese, were determined in six fish species and three crustaceans collected from five sites spanning over 70% of the Ghanaian coastline.

Copper and lead were determined in Barracuda (*Spraena spraena*), the Ribbon fish (*Trichiurus lepturus*), the Sardine (*Sardinella spp*), the Sole (*Cynoflossus senegalensis*), the Sea Bream (*Pagrus coupei*) and the Soldier fish (*Cynapastas marmuratus*). Cadmium and manganese were analyzed in the Blue Crab (*Callinectes sepidus*), the Spiny lobster (*Panilirus regius*) and the edible shrimp (*Crago septempinosus*). Sampling sites included Takoradi, Elmina, Cape Coast, Accra and Tema.

Lead and copper in the fishes ranged 0.25–0.94 $\mu g\,g^{-1}$ fresh weight and 0.40–2.54 $\mu g\,g^{-1}$ dry weight (FW) respectively whilst cadmium and manganese in the crustaceans ranged 0.05–0.083 $\mu g\,g^{-1}$ FW and 0.554–1.404 $\mu g\,g^{-1}$ FW respectively.

The Barracuda accumulated the greatest amount of metals whilst the sardine accumulated the least. With the crustaceans, there was a significant difference between the amounts of the metals accumulated. The blue crab accumulated the greatest and the edible shrimp the least.

The analysis showed that: (i) there was a positive correlation between the metals bioconcentrated and the extent of pollution of the marine waters and (ii) along the Ghanaian Continental Shelf, the extent of pollution was of the increasing order as: Elmina = Cape Coast < Takoradi < Accra < Tema. Pollution of the marine waters could be minimized by control of flow of pollutants from land based activities.

Keywords: Polluted areas; fish; crustaceans; Ghana

*Corresponding author.

INTRODUCTION

The sea provides a relatively constant chemical and physical environment for marine life. Despite the continual natural downhill movement of minerals and nutrients from land to sea, chemical and biological processes in the sea maintain a constant chemical environment. Mankind is contributing consciously and unconsciously to the disruption of these natural balancing mechanism by directly dumping pollutants into the sea or indirectly through the soil, rivers and air. It is believed that such wastes could be either dissolved, diluted and dispersed or decomposed by the sea. This belief is widely acknowledged in Ghana to the extent that drainage systems are treated as disposal sites for both liquid and solid wastes.

Waldichuck (1977) estimated that coastal waters to the edge of the continental shelf constitute only 10% of the world's ocean but over 99% of the fish catch originate from there. Marine pollutants originating from land traverse first the coastal zone. It is evident that before the open sea becomes polluted to any dangerous degree, the coastal environment would have already been intolerably polluted.

Metals, their ions and compounds, are among serious toxic pollutants that enter our natural waters – the sea being the ultimate sink. Although they may exist in trace amounts in the coastal waters, they are concentrated by marine organisms such as fishes and crustaceans by bioconcentration. This is often accompanied by pathogenic effect on the organisms and their predators (Von Westernhagen and Dethlefsen, 1975). Marine organisms bioconcentrate trace metals from the marine waters to the extent that the concentrations in their bodies are many times greater than in the sea water itself (Jenkins and Sanders, 1986). They could then be used as biological indicators of pollution in the seas.

In the present work, we have chosen to use the levels of four metals in fish and crustaceans to identify metal polluted segments of the sea along the Ghanaian Continental Shelf. The metals chosen are copper, cadmium and manganese in two species of crustaceans and six species of fish. We have chosen to determine copper and lead in barracuda (*Spraena spreana*), the ribbon fish (*Trichiurus leptarus*), the sardine (*Sardinella spp.*), the sole (*Cyanoflosus senegalensis*), the sea bream (*Pagirus coupei*) and the soldier fish (*Gynapastes marmuratus*).

Cadmium and manganese were being determined in the exoskeleton of three species of crustaceans; the blue crab (*Callinectes sepidus*), the spiny lobster (*Panilirus regius*) and the edible shrimp (*Crago septemspinosus*). All the species chosen are abundant in the Ghanaian coastal waters. Fish and crustaceans in Ghana are not only important sources of food but also the main supplier of proteins and vitamins in the Ghanaian diet (Adumoah-Bossman, 1984). The six coastal sites for the collection of the organisms span over 250 km of the 350 km long Ghanaian coastline. They include Takoradi, a harbour city in the Western Region, noted for the shipment of raw manganese ore since the colonial times, Elmina and Cape Coast in the Central Region, and Accra (the capital) and Tema, the most industrial city of Ghana and 30 km east of Accra on the Greenwich meridian. The sites were chosen according to the presence or absence of industrial activities and population densities.

MATERIALS AND METHODS

Sample Collection

The fish and crustacean species and the corresponding surface waters were collected with the help of experienced fishermen at the sites. As much as possible, the same personnel were used in the collection and the positions of collection were also maintained. The use of metals was avoided both in the collection and storage. The live samples were wrapped in polythene bags, labelled and placed in ice chests and shipped to the laboratory for storage in deep freezers at $-5°C$ for two weeks. Collection of the samples were done in a six month period lying between the lean fish season and the high season of Ghana.

Sample Treatment

With the fish, the thawed muscles were used and with the crustacean, the exoskeletons. The exoskeleton acts as a storage organ and hence give a true picture of accumulation.

The water and the organisms were completely digested as presented according to the FAO prescribed method (Jenkins and Sanders, 1986;

FAO, 1983; FAO, 1982). From the diluted digest, the metal concentrations were determined by Flame Atomic Absorption spectrometry using Shimadzu AA6401F Atomic Absorption Flame Emission Spectrophotometer.

RESULTS AND DISCUSSIONS

The area of study and sample sites are shown in Figure 1. The range of the metal concentrations in exoskeletons of crustaceans and in fish

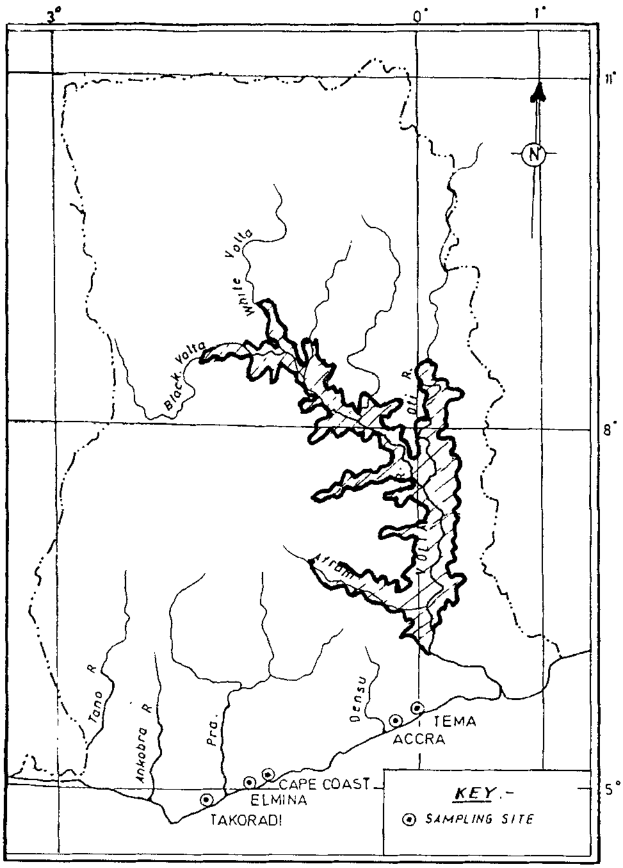

FIGURE 1 Ghana: map to indicate sea sampling sites.

muscles are shown in Tables I and II. Also shown in Table III is the range of length and body weight of fish and crustaceans used in this study.

Metals at Sites of Collection

Figure 2 shows the concentration of the metals at the five collection sites in the Ghanaian Continental Shelf. It is clear from the figures that the order of accumulation of the metals at the site range: Tema > Accra > Takoradi > Cape Coast ≒ Elmina.

TABLE I Range and mean concentrations of invertebrates with cadmium and manganese in the exoskeleton of 3 species. (FW is fresh weight)

Species (Crustaceans)	*Range and mean of Cd* ($\mu g\, g^{-1} FW$)	*Range and mean of Mn* ($\mu g\, g^{-1} FW$)
Blue Crab	0.06–0.08 Mean: 0.07 ± 0.01*	0.61–1.4 Mean: 1.05 ± 0.41*
Spiny Lobster	0.05–0.08 Mean: 0.07 ± 0.01*	0.61–1.38 Mean: 1.02 ± 0.38*
Edible Shrimp	0.05–0.08 Mean: 0.06 ± 0.01*	0.55–1.26 Mean: 0.97 ± 0.34*

*Standard error.

TABLE II Range and mean concentrations of lead and copper in the muscles of six species of fish from the Ghanaian Coastal Waters. (FW is fresh weight)

Fish species	*Range and mean of Pb* ($\mu g\, g^{-1} FW$)	*Range and mean of Cu* ($\mu g\, g^{-1} FW$)
Sardine	0.25–0.50 Mean: 0.38 ± 0.02*	0.44–1.60 Mean: 0.94 ± 0.10*
Soldier Fish	0.35–0.54 Mean: 0.46 ± 0.02*	0.58–1.65 Mean: 1.12 ± 0.10*
Sea Bream	0.34–0.58 Mean: 0.40 ± 0.02*	0.59–1.64 Mean: 1.12 ± 0.09*
Sole	0.43–0.72 Mean: 0.57 ± 0.03*	1.15–2.23 Mean: 1.02 ± 0.40*
Barracuda	0.42–0.75 Mean: 0.59 ± 0.04*	1.29–2.04 Mean: 1.94 ± 0.11*
Ribbon Fish	0.35–0.67 Mean: 0.53 ± 0.20*	0.86–1.98 Mean: 1.40 ± 0.11*

*Standard error.

TABLE III Length and body weight of fish and crustaceans used

Species	*Length range (cm)*	*Body weight range (g)*
Sardines	13.7–23.1	24.35–121.36
Soldier Fish	12.7–32.3	38.66–268.23
Sea Bream	14.4–20.0	58.43–74.18
Sole	21.6–41.2	112.66–361.77
Barracuda	18.8–31.40	67.11–156.26
Ribbon Fish	55.3–93.1	151.68–229.87
Blue Crab	7.6–8.7	41.43–51.74
Spiny Lobster	16.4–19.5	49.25–62.99
Edible Shrimp	7.9–9.8	6.44 ± 7.02

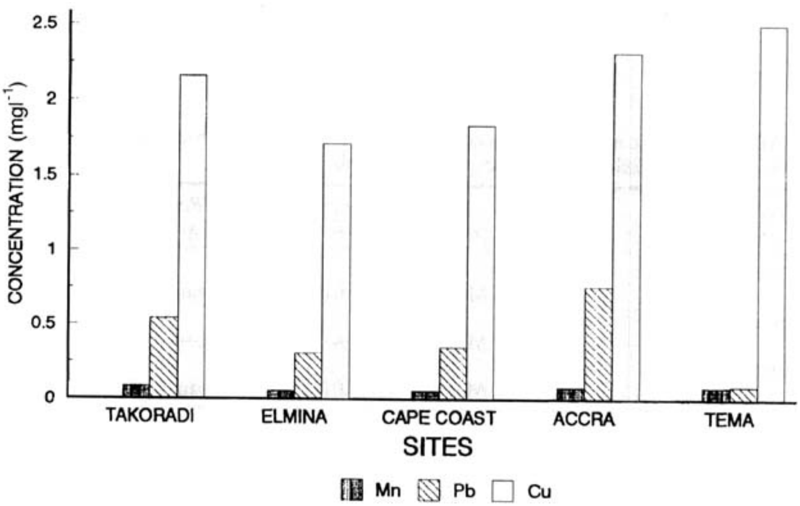

FIGURE 2 Levels of the metals in sea water at the collection sites.

Manganese and Cadmium in the Crustaceans

The concentration of cadmium and manganese bioaccumulated by the three species of crustaceans at each collection site, reflect the extent of contribution from natural as well as industrial, agricultural and urban input to the continental shelf. Cities of Takoradi, Accra and Tema support over 60% of all industrial activities in Ghana. Cape Coast is a purely educational centre with little or no industrial activity. Apart from the small fishing activities at both Cape Coast and Elmina, the only industry in the area is both a soap and a brake lining factory which contribute in a small way to the degradation of the environment. Figure 3 shows that the higher concentration of the metals were found in Takoradi, Tema and Accra. Table I shows the distribution of the metals in the crustaceans with the blue crab accumulating the highest, followed by the spiny lobster and then the edible shrimp. The same pattern of distribution in their exoskeleton is repeated for the concentration of the metals in the sea water. This is shown in Figure 3. There was a positive linear correlation between the concentrations of the metals in the sea and that in the exoskeleton of the organisms. The higher the concentration in the sea water, the greater the amount of metal bioconcentrated. Much more manganese was accumulated than cadmium (Fig. 4) especially at Takoradi where there is much more manganese shipment activity. The metals in the waters were lower than expected.

Lead and Copper in Fishes

Considering the sampling sites, it is clear from Table II that species of fish from Tema coastal waters had the highest mean concentration of both lead and copper (0.94–2.54 $\mu g\, g^{-1}$ FW) and in Figures 5 and 6. There was also a positive correlation between the amounts of the metals present in the muscles to the amounts present in the coastal waters. In general the distribution of the metals in fish with respect to

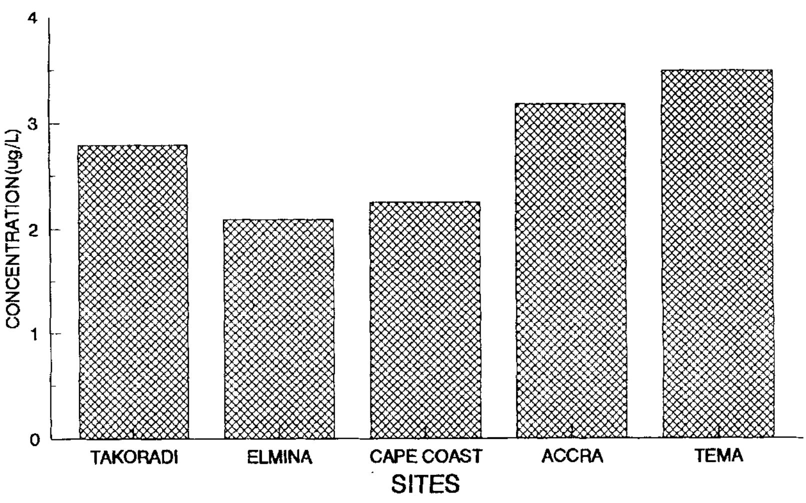

FIGURE 3 Total metal concentration at the collection sites.

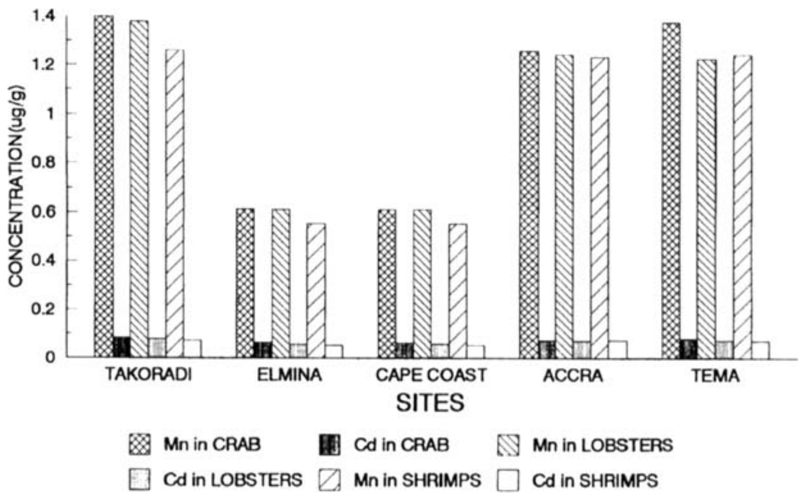

FIGURE 4 Mean concentration of cadmium and manganese in crustaceans at the collection sites.

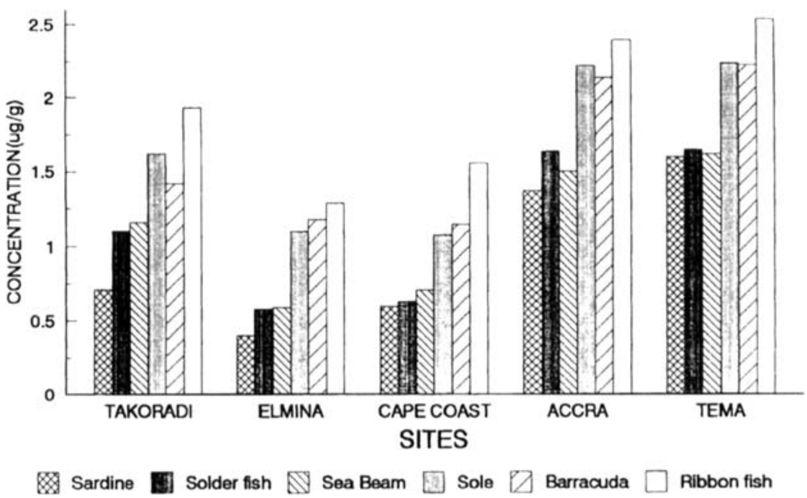

FIGURE 5 Mean concentration of copper in fish at the collection sites.

site followed the same pattern of distribution of the metals in the crustaceans. The highest concentrations occurred in Tema, Accra and then Takoradi, with the lowest occurring at Elmina and Cape Coast. This pattern may not be observed in every locality especially where

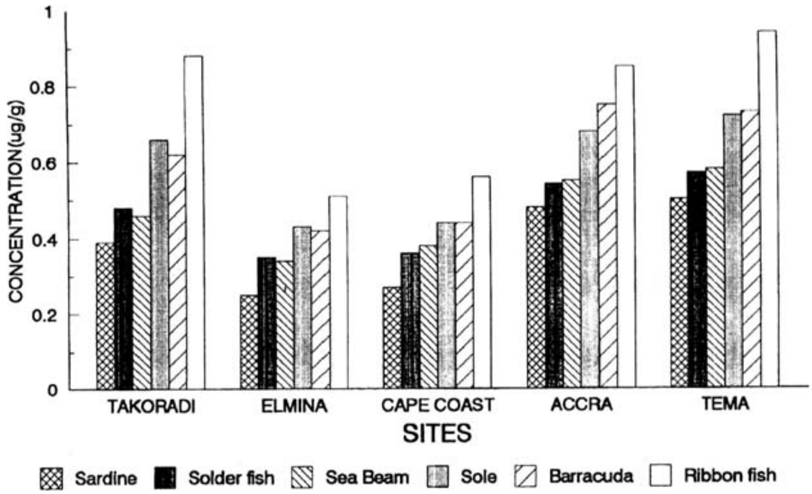

FIGURE 6 Mean concentration of lead in fish at the collection sites.

there are seasonal variations for instance in estuarine environments where the salinities, temperatures and alkalinity of the water vary greatly (Engel and Fowler, 1979).

The variation in the concentration at the sites was attributable to the degree of industrialization and urbanization which increase the concentration of the metals in the sea water from manufacturing and processing plants. In Tema, the oil processing plants and agrochemical factories release large volumes of these metals into the sea. Until 5 years ago, the Tema Oil Refinery was importing lead in the form of tetraethyl lead as an additive for gasoline. There are also battery manufacturing factories which also contribute to the lead and zinc concentrations. Copper is largely released from metal scraps and worn out pipelines. The concentration of the metals are, however, lower in Elmina and Cape Coast.

In general the order of distribution accumulation of the metals in the coastal waters and in the muscles of fish and exoskeleton followed the order Tema > Accra > Takoradi > Cape Coast = Elmina. This shows that the most eastern portion of the country, where there is much industrial activities and consequently high population densities, were more polluted than the Central and Western portion of the Ghanaian continental shelf. Comparing the concentrations of the

Ghanaian Continental Shelf to those of other coastal waters, it is evident that the metal pollution of the waters in Ghana was lower, but gives cause of concern. For example, copper in Bombay Harbour ranges 2.6–7.34 $\mu g\,l^{-1}$ (Granapathy and Pillai, 1975) and that of the Arabian Open Sea ranges 2.7–16.8 $\mu g\,l^{-1}$ (Sreekuman, 1976) and for the Tarapur Coast the range was 13.35–45.12 $\mu g\,l^{-1}$ (Sarma, 1967).

CONCLUSIONS AND RECOMMENDATIONS

The ribbon fish could be used in future for further studies along the Ghanaian coastal waters since it tended to accumulate the metals to a greater extent. Similarly though there was no significant difference between the metals accumulated by the crustaceans, the blue crab is preferred because of its availability.

The coastal environment of Ghana appeared stable with respect to changes in salinity, temperature and pH. Hence a positive correlation existed between the amounts of metals in solution and that bioconcentrated by the organisms.

It was also observed that the manganese at the Takoradi harbour was fairly high as compared to the other sites. This could be attributed to the deposition of materials from shipment of manganese ore at the harbour.

The order of metal contamination was Elmina = Cape Coast < Takoradi < Accra < Tema.

The western and the eastern portions of the Ghanaian Continental Shelf were more polluted. The central stretch was much cleaner though the waters were less diluted by fresh water.

All industrial effluents must be properly pretreated before entering the sea. Early action should to be taken to avoid further contamination of the Ghanaian coastal water; this calls for the setting up control limits. Monitoring of the waters with respect to the organic and inorganic sources of pollutants should be extended to cover the entire Ghanaian Continental Shelf.

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References

Adumoah-Bossman, J. (1984) Aquatic Biology, CSIR (Ghana). Personal Communication.

Engel, D. W. and Fowler, B. A. (1979) Factors influencing cadmium accumulation and its toxicity to marine organisms, *Environ. Health Persp.*, **28**, 81–88.

FAO (1983) Determination of total cadmium, zinc, lead and copper in selected marine organisms by Atomic Absorption Spectrometry (1982) UNEP, Reference Methods for Marine Pollution Studies, Vol. 11 – Prepared in Co-operation with FAO.

FAO (1983) *Manuals of Methods in Aquatic Environment*, FAO, Rome, pp. 8–10.

Granapathy, S. and Pillai, K. C. (1975) Distribution of copper in the aquatic environment of Bombay Harbour, *J. Mar. Biol. Assoc. India*, **17**, 545–554.

Jenkins, K. D. and Sanders, B. M. (1988) Relationships between free cadmium ion activity in seawater, cadmium accumulation and subcellular distribution and growth in polychaetes, *Environ. Health Perspect.*, **65**, 205–210.

Sarma, T. P. (1967) Geochemical investigations of Tarapur Coast. *Proceedings of the Symposium on Indian Ocean held at New Delhi*, Bull. N. 1-3.1, **38**, 308–318.

Sreekuman, C. (1976) Minor and trace elements in the marine environment of the West Coast of India. AEET/HP/PM-J.

Von Westernhagen, H. and Dethlefsen, V. (1975) Combined effects of cadmium and salinity on development and survival of flounder eggs, *J. Mar. Biol. Assoc.*, U.K. **55**, 945–957.

Waldichuk, M. (1977) Global Marine Pollution: An Overview, UNESCO, *IOC Tech.: Ser.*, **8**, 96.