

# Investigation of Ecosystem Health of International Meighan Wetland

Bahman Shams Esfand Abad (✉ [bshams1357@gmail.com](mailto:bshams1357@gmail.com))

Islamic Azad University of Arak

---

## Research Article

**Keywords:** Heavy metals, Pollution coefficient, Meighan wetland, Sediment.

**Posted Date:** October 29th, 2021

**DOI:** <https://doi.org/10.21203/rs.3.rs-1018840/v1>

**License:**  This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

---

# Abstract

**Background:** The aim of this study was to evaluate the ecosystem health of Meighan Wetland of Arak.

**Methods:** To evaluate the Meighan Wetland of Arak, the status of benthic organisms and other parameters, sampling of sediments of the wetland floor was performed at 10 points of the wetland and at 5 replications at each point. Heavy metal pollution, biological, and water quality indices were also evaluated. Then, the map of ecosystem health was prepared.

**Results:** The results showed that except for the nickel, zinc and lead, for other elements and compounds (EC, Na, Cl, Mg, Ca, HCO<sub>3</sub>, SO<sub>4</sub> and TDS), the minimum and maximum values belonged to stations 3 and 6, respectively. In the case of copper, zinc and lead, the lowest concentration was seen in the northwestern part of the wetland and the highest in the western and southeastern parts of the wetland.

**Conclusion:** The high amount of the mentioned elements and compounds in station 6 may be due to the activity of a factory that produces sodium sulfate in the northern part of the wetland, which causes changes in the wetland ecosystem by removing sediments from the wetland floor. The high level of the copper, zinc and lead in the southern part of the wetland can be due to urban and domestic wastewaters that enter the wetland from the southwest of the wetland through the outlet channel of Arak refinery.

## Introduction

Wetlands are valuable ecosystems that have a wide variety of functions to protect biodiversity, multiple natural, economic and social values (Fallah, 2017 & Fakhran).

The Ramsar Convention defines wetlands as swamps, sludges, lakes and rivers, natural or artificial water, whether permanent or temporary, in which fresh, bitter and salty water are found stagnant or flowing. The survival of many plant and animal species depends on the existence of wetlands, which are dynamic and complex aquatic ecosystems. Among the 84 wetlands of international importance in Iran, 24 sites are included in Ramsar sites, which have an area of about 1486438 hectares and cover approximately eight hundred percent of the area of Iran. There are about 60 large and small playas in the inland plateau of Iran, to which all the inland watersheds of the country end. These wetlands and aquatic ecosystems are valuable assets that are all unique in their kind (Ramezani Ghavamabadi & Sanaipour, 2013).

Wetlands are more important, especially in arid and semi-arid regions such as Iran, because wetlands can reduce the effects of climate change in various ways, so the decline and destruction of wetlands intensifies the effects of climate change (Fallah, & Fakhran, 2017).

Meighan Wetland of Iran is located 15 km northeast of Arak and is one of the important habitats of 140 species of birds. In addition to the main role in biodiversity, its seasonal lake has direct effects on controlling sand, salt and air pollution sources in Arak. It is like a bowl of water that stretches over an area of 5,000 square feet (Figure 1).

It is also an important winter habitat that attracts countless migratory birds especially, at least 5,000 Common Cranes per year from October to December (Behrouzi-Rad *et al.* 1997).

This area is also the habitat of unique plant species that has a very beautiful landscape. Since Meighan wetland of Arak has been affected by various stresses and environmental pollutants such as the entry of agricultural and urban industrial effluents. The effluent entering the wetland has reduced soil salinity in the southwestern part of the wetland and has helped to create a dense cover of *Cyperus Cyperus eremicus* (Ansari, 2008).

Pourimani et al. (2020) show that the presence of radium and thorium in sediments and water samples from the Arak wastewater treatment plant is less than the global average and its amount in the soil of the region is moderate. The specific activity of  $^{40}\text{K}$  is equal to the global average and the soil sediments around the areas are polluted with  $^{137}\text{Cs}$  synthetic radionuclide, similarly. Radiological maps show that  $^{226}\text{Ra}$  is mostly deposited in the vicinity of the inlet (S1) and  $^{137}\text{Cs}$  is deposited in remote locations. Fortunately, radiological parameters of water quality are within acceptable limits and is not considered a risk factor for the local population.

the presence of non-native species, land use change, the study of spatial and temporal changes of pollutants is one of the objectives of this study.

## Materials And Methods

In order to evaluate the health of aquatic ecosystems and also to investigate the status of benthic organisms and other parameters, sampling of wetland sediments was performed in 5 repetitions from 10 points of the Meighan wetland (Figure 2).

The following various indicators were used to assess the ecosystem health of the wetland:

- The AZTI Marine Biotic Index (AMBI), which is obtained from the ratio between species resistant to stress gradients and increased pollution. This index is based on the distribution and frequency of soft bed communities in 5 ecological groups based on sensitivity and resistance, organisms against stress gradient and increased pollution. Due to the impact of humans on the environment, this index is used to measure the evolution of the environmental situation in certain areas. One form of AMBI is the classification of species into different groups according to the species' response to infection.

$$(1) \text{AMBI} = [(0 \times \% \text{EG1}) + (1.5 \times \% \text{EG2}) + (3 \times \% \text{EG3}) + (4.5 \times \% \text{EG4}) + (6 \times \% \text{EG5})] / 100$$

While, %EG1= Sensitive to disorder, % EG2= Indifferent, % EG3= Tolerance to the disorder, % EG4= Regular opportunist and % EG5= Ordinary opportunist.

- The Hilsenhof Biotic Index (HBI) estimates the overall tolerance of a community in a sample area, which is weighed against the relative abundance of each classification group (family, genus, etc.). In this method, water is classified in terms of pollution with organic matter and the amount of index is

calculated using the following equation. Accordingly, the higher index is a marker of the higher presence of animals with resistance, and this means high pollution of the study source.

- The business confidence index (BCI) provides information on future developments, based upon opinion surveys on developments in production, orders and stocks of finished goods in the industry sector. This index is designed to assess the environment and destructive or non-destructive systems in relation to the reference conditions and based on the response of benthic organisms to environmental stressors. This index includes: 1) Shannon-Wiener diversity index 2) Frequency for Tubificida 3) Percentage abundance of bivalves 4) Percent abundance of capitelicidae family 5) Percentage abundance of two species.

## Results

The AZTI Marine Biotic Index (AMBI), shows a good ecological status. The relationship between different indicators related to the health of Meighan wetland ecosystem and the concentration of different compounds in each station shows that there is no significant correlation between them (except in terms of acidity and nickel concentration). The value of regression coefficient in the mentioned parameters according to the graphs is higher than 0.5 and this shows a significant relationship between BC indices, nickel concentration and acidity (Diagrams 1-13).

The results show that the highest and lowest concentrations were obtained for copper, nickel, lead and zinc in mg/kg of sediments of the wetland floor dry weight. Based on sampling station, except for nickel, zinc and lead, for other elements, the lowest and highest values in mg/kg are for stations 3 and 6, respectively. In 3 and 6 stations, the lowest and highest values were as follows: 4.88 Mg/kg and 6.9 mg/kg for calcium 3.98 and 4.96 Mg/kg for magnesium 62.5 and 7.01 Mg/kg for sodium 6.18 and 7.71 Mg/kg for sodium sulfate. EC is equal to 85/1458 and 34/1821 ppm, while 3.69 and 4.60 are for HCO<sub>3</sub>, 67/4 and 83/5 are for chlorine (Table 2).

For pH scale values, the lowest (7.35 mg/kg) and highest (7.94 mg/kg) are for stations 3 and 7, respectively. In the case of nickel, the lowest (0.47 mg/kg) and highest (1.28 mg/kg) belong to stations 7 and 2, respectively. In the case of zinc, the lowest (0.47 mg/kg) and highest (1.28 mg/kg) are related to stations 3 and 10, respectively. In the case of lead, the lowest (0.25 mg/kg) and highest (0.64 mg/kg) are related to stations 2 and 3, respectively. The range of concentration changes of four heavy metals obtained in the sediments of the bottom of Meighan wetland in Arak coastal region in terms of mg / kg were for copper, nickel, lead and zinc, respectively.

The results of pollution factor analysis showed that most of the samples are in the category of unpolluted to low polluted coefficient. So that for lead metal, all stations and nickel, except for the first 3 stations, the rest of the stations are in the lower pollution class (Table 5).

Also, in order to determine the situation of the region in terms of concentration of different elements, relevant maps were prepared. It was found that the levels of Ca, EC, HCO<sub>3</sub>, Mg, Na, PH, Cl and TDS in the southwest of the wetland are minimal and reach their peak in the northern part of the wetland. In the case

of copper, zinc and lead, the lowest concentration is seen in the northwestern part of the wetland and the highest concentration is seen in the western and southeastern parts of the wetland (Table 5). According to BC and BI maps, the lowest concentration of pollution is concentrated in the southwest of the wetland and the lowest in the northwest of the wetland.

## Discussion And Conclusion

In the present study, the concentrations of heavy metals (nickel, copper, zinc and lead) in the sediments of the bottom of Meighan wetland in Markazi (central) province were investigated. In the end, the results showed that the highest and lowest concentrations were obtained for heavy metals of copper, nickel, lead and zinc in mg/kg dry weight, respectively.

Examination of physicochemical characteristics of sampling stations showed that except for heavy metals nickel, zinc and lead and pH, for other elements and compounds (EC, Na, Cl, Mg, Ca, HCO<sub>3</sub>, SO<sub>4</sub> and TDS), the lowest and highest values it corresponds to stations 3 and 6, respectively. The high amounts of elements and compounds in station 6 can be due to the activity of sodium sulfate factory in the northern part of the wetland, which changes the ecosystem of the wetland by removing sediments.

To determine the amount of sediment pollution to heavy metals, the concentration of compounds in the area should be compared with a known standard. In the meantime, comparison with the existing standards for the same region is one of these methods. In this study, due to the lack of specific standards for pollution in the study area, global and existing standards in other countries were used. However, comparisons should be made with caution because there are different differences in properties or physicochemical parameters between their concentrations at different locations and times (38).

In fact, their average concentration was more or less depending on the type of metal and the place of measurement. But in general, the concentration of metals in the sediments of the study area was the same as the values determined for other studies conducted in Meighan wetland. In the case of heavy metals, minor pollution was observed in some parts of the region, so that in the case of nickel, the lowest (0.47) and highest (1.28) values were related to stations 7 and 2, respectively. In the case of zinc, the lowest (0.47) and highest (1.28) values were related to stations 3 and 10, respectively. In the case of lead, the lowest (0.25) and highest (0.64) values were related to stations 2 and 3, respectively.

These findings are consistent with the results of Vaezi et al. (2013) in the sediments of Mahshahr estuary of the Persian Gulf and also Haghshenas et al. (2017) in the Pars Energy Special Economic Zone in the southeast of Bushehr, Persian Gulf.

Most of the nickel is colloidal and is heavily deposited in estuaries and beaches. High nickel in some areas may be due to point sources or possibly the entry of municipal sewage sludge. Because municipal wastewater also has a significant amount of nickel with it (Darvishnia et al., 2015). and compounds

Zinc is the twenty-fifth most abundant element in the earth's crust, making up between 0.0005 and 0.02% of the earth's crust. Some heavy metals, such as copper and zinc, are essential micronutrients that in toxic concentrations have toxic and adverse effects on growth, while another element, such as lead, plays no major role in plant metabolism, although naturally it exists in soil (Pendias and Pendias, 1992).

A possible source of increasing concentrations of zinc and copper is the discharge of construction waste and household wastewater into the Meighan wetland. In the case of copper, in a study conducted in Italy, the amount of copper was 5.1 mg / kg, which is consistent with our findings in this study (Tavassoli et al., 2009). Copper concentrations in unpolluted soils are between 2 and 40 mg / kg, and copper toxicity is commonly observed in acidic soils with low cation exchange capacity (Mirlin et al., 2007). Sources of copper entry are soil production, metal production, mining, municipal, industrial and agricultural wastes, fertilizers and agricultural chemicals. Agricultural practices add liquid and solid animal manure or mineral fertilizers to the soil (Chunfa et al., 2010).

Examination of the relevant maps of concentrations of different elements and compounds shows that in general the values of Ca, EC, HCO<sub>3</sub>, Mg, Na, PH, Cl and TDS in the southwest of the wetland are minimal and reach their peak in the northern part of the wetland. In the case of copper, zinc and lead, the lowest concentration is seen in the northwestern part of the wetland and the highest concentration is seen in the western and southeastern parts of the wetland. The high level of these elements and compounds in the southern part of the wetland can be due to urban and domestic effluents (Zou et al., 2007) which enter the wetland from the southwest of the wetland through the outlet of Arak water treatment plant.

Finding the comparison of metal concentrations in the studied sediments with the earth crust and other coastal sediments of different regions showed that the obtained concentrations are less than the earth crust. In addition, their concentration was in the range of metal concentrations in similar studies conducted by other researchers in different regions. These studies include such things as; Nowruzzi et al. (2016); Dehghani et al. (2014) and Rabbani et al. (2006); Hashemi et al. (2013) pointed out.

Regarding BC and BI maps, studies indicate that the lowest concentration of pollution is concentrated in the southwest of the wetland (entry of treated wastewater from Arak into the wetland) and the highest concentration of pollution is concentrated in the northwest of the wetland (sodium sulfate Company). Therefore, the southern and southwestern areas of the wetland have relatively better conditions than its northern and northwestern areas.

The results of pollution factor analysis showed that most of the samples are in the category of unpolluted to low pollution coefficient. So that for lead metal, all stations and nickel, except for the first 3 stations, the rest of the stations are in the lower pollution class in terms of the pollution factor of the zoning map of different elements and compounds.

The correlation between the physicochemical properties of the measuring stations along with their biological coefficient shows that there is a positive correlation between the biological coefficient (BC) and PH scale and HCO<sub>3</sub> concentrations and a negative correlation between BC and Ni. There is also a

correlation between copper and elements such as lead, potassium and nickel. This issue can be a sign of the common origin of their production from the rocks of the region and on the other hand shows the human contribution of the production of these metals due to urban development around the Meighan Wetland (Khodabakhshi et al., 2017).

Today, heavy metals pollution in aquatic ecosystems due to properties such as toxicity, carcinogenic potential and high mutagenicity, very long stability, high accumulation at different levels of the food chain are one of the biggest problems and concerns worldwide.

Therefore, in order to determine the health of the wetland, the pollution conditions of this ecosystem were evaluated. This evaluation was done by examining the samples taken from the sediments of the wetland floor and also examining the water quality of the wetland based on the indicators used and the biological index of wetland health.

According to studies, it was found that the health of the wetland is in two floors, non-polluted and low pollution. In general, the situation in the wetland area indicates a situation with relatively low pollution in the area. The results of pollution factor analysis showed that most of the samples are in the category of unpolluted to low pollution coefficient. So that for lead metal, all stations and nickel, except for the first 3 stations, the rest of the stations are in the lower pollution class. In areas that are not polluted, it indicates that in those areas either the required data may be not available enough or they are well protected. In the northern parts of the wetland, due to the presence of sodium sulfate plant, the concentration of salinity elements increases as a constant trend.

Examination of data related to heavy metals shows that the wetland area is in a non-polluted to low pollution state from the point of view of heavy metals. Therefore, it can be concluded that heavy sediments on the bottom of the wetland are not a good indicator of ecosystem health and cannot reflect the reality of the wetland well. In general, the effect of mineralization in the region on the concentration of elements and compounds in the sediments of the wetland floor of the deposit area as a natural and terrestrial factor and the effect of Arak wastewater treatment plant effluent as an anthropogenic factor in increasing the concentration of elements and compounds is obvious.

In this regard, it is suggested that periodic monitoring of pollutants and conducting appropriate scientific research in the region be strengthened. Also, new warning systems and appropriate protective measures should be taken by executive organizations in this regard. Also, evaluations of the wetland area should be done periodically to effectively contribute to the sustainable development of the wetland.

## References

1. Ansari Amir, Mohammad B. Sadough & Bahman S. Esfandabad, Ecological Investigation of the Common Crane *Grus grus* in Mighan Wetland, Markazi Province, Central Iran, *Podoces*, 2008, 3(1/2): 73–78.

2. Cheng, H.H., Koskinen, W.C. (2002). Interactions of minerals-organic matter-living organisms on the fate of allelochemicals and xenobiotic in soil: A methodological evaluation, in developments in Soil Science, P.M.H.J.M.B. A. Violante and L. Gianfreda, Editors, Elsevier. 135-45.
3. Cui, B., Yang, Z., (2002). Establishing an Indicator System for Ecosystem Health Evaluation on Wetlands. A Theoretical Framework. *Acta Ecol Sin.*; 22(7): 1005-11 (in Chinese).
4. Cui, Q., Wang, X., Li, D., Guo, X. (2012). An ecosystem health assessment method integrating geochemical indicators of soil in Zoige wetland, southwest China. *Procedia Environmental Sciences* 13: 1527-1534.
5. Cui, B., He, Q., Gu, B., Bai, J., Liu, X. (2016). China's Coastal Wetlands: Understanding Environmental Changes and Human Impacts for Management and Conservation. *Wetlands*, **36**, 1–9.
6. Danley, B., Widmark, C. (2016). Evaluating conceptual definitions of ecosystem services and their implications. *Ecological Economics*, 126, 132-138.
7. Darvishnia, Z, Riahi Bakhtiari, A, Kamrani, E, et al. (2015). Bioaccumulation of Heavy Metals (Pb, Fe & Zn) in the Tissues of Skeletal Coral family, Faviidae and Surrounding Sediments in the South of Qeshm Island-The Persian Gulf. *Journal of Aquatic Ecology*. 2015; 5(1):77-87. (Persian)
8. Dehghani, M., Nabipour, I., Dobaradaran, S., et al. (2014). Cd and Pb Concentrations in the Surface Sediments of the Asaluyeh Bay, Iran. *J Community Health Res*; 3(1): 22-30. (Persian)
9. De Lange, H. J., Sala, S., Vighi, M., & Faber, J. H. (2010). "Ecological vulnerability in risk assessment-a review and perspectives", *Science of the Total Environment*, 408(18), 3871-3879.
10. Detenbeck, N. E., Batterman, S. L., Brady, V. J., Brazner, J. C., Snarski, V. M., Taylor, D. L., ... & Arthur, J. W. (2000). "A test of watershed classification systems for ecological risk assessment", *Environmental Toxicology and Chemistry*, 19(4), 1174-1181.
11. Giesen, W. (2011). Management guidelines for implementation biodiversity management of wetlands. IRI department of environment, United Nations development programme, Global environment facilities (In Persian).
12. Hamed, M.A., Lotfy, H.R., Kandawa-Schulz, M. (2007). Chemical forms of copper, zinc, lead and cadmium in sediments of the northern part of the Red Sea, Egypt. *Pakistan J Mar Sci.*, 16(2): 69-78.
13. Hashemi, S.J., Riahi Bakhtiari, A., Lak, R. (2013). Source Identification and Distribution of Lead, Copper, Zinc, Nickel, Chromium and Vanadium in Surface Sediments of Caspian Sea. *J Mazand Univ Med Sci* 2013; 22(1): 36-50. (Persian)
14. Jain, C.K., Sharma M.K. (2001). Distribution of trace metals in the Hindon River system, India. *Journal of hydrology*, 15; 253(1):81-90.
15. Johnson, W.C., Millett, B., Gilmanov, T., Voldseth, R., Guntenspergen, G., Naugle, D. (2005). "Vulnerability of Northern Prairie wetlands to climate change, *Bioscience*, 55(10): 863-872.
16. Jones, K., Lanthier, Y., Voet, P., Valkengoed E., Taylor, D. and Fernandez-Prieto, D., (2009). Monitoring and assessment of wetlands using Earth Observation: The GlobWetland project, *Journal of Environmental Management*, 90: 2154–2169.

17. Krchnak, K. M., Smith, D. M., Deutz, A. (2011). Putting nature in the nexus: investing in natural infrastructure to advance water-energy-food security. *Bonn2011 Conference: The Water, Energy and food security nexus-solutions for the green economy*.
18. Lu, C., Wang, Z., Li, L., Wu, P., Mao, D., Jia, M., Zhangyu Dong, Z. (2016). Assessing the conservation effectiveness of wetland protected areas in Northeast China. *Wetlands Ecol Manage* (2016) 24:381–398. DOI 10.1007/s11273-015-9462-y
19. Malekmohammadi, B., & Rahimi Blouchi, L. (2014). Ecological risk assessment of wetland ecosystems using Multi Criteria Decision Making and Geographic Information System. *Ecological indicators*, 41, 133-144.
20. Maltby, E., (1992). "Towards practical policies of wetland conservation and wise use", Proceedings of the Wetland Forum, Hokkaido, Japan, 205–217.
21. McCartney, M. P., Acreman, M. C. (2009). *Wetlands and water resources, in: the wetlands handbook*. Wiley-Blackwell, London, UK, 357-381.
22. MEA (Millennium Ecosystem Assessment), (2005). *Ecosystems and human well-being: wetlands and water synthesis*. World resources institute, Washington, DC.
23. Mirzaeia, M., Solgib, E. and Mahiny, A., (2015). Evaluation of Surface Water Quality by NSFWQI Index and Pollution Risk Assessment, Using WRASTIC Index. *Journal of Homepage*. 5(4), 264-277 (In Persian).
24. Mitsch, W. J., Gosselink, J. G. (2015). *Wetlands*. 2nd Ed., Wiley, New Jersey.
25. Muangthong, S., Clemente, R.S., Babel, M.S., Gallardo, W., & Weesakul, S. (2011). Assessment of wetland ecosystem health in Lower Songkhram, Thailand. *International Journal of Sustainable Development & World Ecology*, DOI:10.1080/13504509.2011.620643
26. Noroozi, K.V., Dobaradaran, S., Nabipour, I., et al. (2016). A new bio-indicator, shell of *Trachycardium lacunosum*, and sediment samples to monitors metals (Al, Zn, Fe, Mn, Ni, V, Co, Cr and Cu) in marine environment: The Persian Gulf as a case. *J Environ Health Sci Eng* 14(1): 16.
27. Pantus, F.J., Dennison, W.C. (2005). Quantifying and evaluating ecosystem health: A case study from Moreton Bay, Australia. *Environ Manage*, 36(5):757-71.
28. Piralizadeh, A., Ebrahimi, E. (2017). Introduction of Several Biological Indices for the Assessment of River Water Quality. *Journal of Water and Sustainable Development*, 3(2): 35-42.
29. Pourimani Reza, Ramin Fardad, Hasan Khalili (2020). Radiological Hazard Assessment of Radionuclides in Sediment and Water Samples of International Meighan Wetland in Arak, Iran, *Iranian Journal of Medical Physics*. Volume 17, Issue 2 - Serial Number 2, Pages 107-113.
30. Rabbani M, Asadullah J, Sharif A. (2006). Measurement of Heavy Metals lead, nickel and mercury in water and sediments in the Persian Gulf area of operations Assaluyeh. *Journal of Environmental Sciences and Technology*, 9(3): 23-33. (persian)
31. Ramsar convention on wetland, (2013). [www.ramsar.org](http://www.ramsar.org)

32. Thai Baan Research. (2005). Ecology and local history of the seasonally flooded forest in the Lower Songkhram Basin. Bangkok (Thailand): World Conservation Union (IUCN).
33. Vaezi, A., Karbasi, A., Vali Khani Samani, A., Heidari, M., Fakhraie, M., Rahmati, A. (2013). Zoning, distribution and origin of total petroleum hydrocarbons (TPH) and metallic pollutants in sediments of the estuary Mahshahr, Persian Gulf. *Journal of Environmental Science and Technology*, 16:1-19 (in Persian).
34. Washington State Department of Ecology. (1993). Washington State Wetlands Rating System: Western Washington. Second Edition. Publication Washington State Department of Ecology, Olympia,
35. Wang, Z.M., Zhang, B., Zhang, S.Q., Li, X.Y., Liu, D.W., Song, K.S., Li, J.P., Li, F., Duan, H.T. (2006). Changes of land use of ecosystem service values in Sanjiang Plain, Northeast China. *Environ Monit Assess* 112:69–91.
36. Williams, L.R.R., Kapustka, L.A. (2000). "Ecosystem vulnerability: a complex interface with technical components", *Environ Toxicol Chem*; 19:1055-8.
37. Zhang, S.Q., Wang, A.H., Zhang, J.Y., Zhang, B. (2003). The spatial temporal dynamic characteristics of the marsh in the Sanjiang Plain. *J Geogr Sci* 13:201–207.
38. Zhou, D., Gong, H., Wang, Y., Khan, S., & Zhao, K. (2009). "Driving forces for the marsh wetland degradation in the Honghe National Nature Reserve in Sanjiang Plain, Northeast China". *Environmental modeling & assessment*, 14(1), 101-111.
39. Zhou F, Guo H, Hao Z. (2007). Spatial distribution of heavy metals in Hong Kongs marine sediments and their human impacts: a GIS based chemo-metric approach. *Mar Pollut Bull*; 54(9): 1372-84.

## Tables

Table1-relationship between biologic factors and AMBI

<b>AMBI</b>	<b>5.5-7</b>	<b>4.3-5.5</b>	<b>3.3-4.3</b>	<b>1.2-3.3</b>	<b>0-1.2</b>
<b>Ecologic condition</b>	worth	weak	medium	good	excellent
<b>Species richness</b>	0-15	30-15	45-30	60-45	60<
<b>Diversity</b>	0-1.2	2.4-1.2	3.6-2.4	3.6-4.8	4.8<

Table 2 -statistical characteristics of variables

<b>kurtosis</b>	<b>skewness</b>	<b>variance</b>	<b>2Sd</b>	<b>average</b>	<b>max</b>	<b>min</b>	<b>Variable</b>
4.755	2.026	3975.969	63.05529	941.9130	1100.72	881.65	TDS
4.755	2.026	10885.894	104.33549	1558.5650	1821.34	1458.85	EC
4.791	2.032	.121	.34785	5.2130	6.09	4.88	Ca
4.762	2.031	.080	.28223	4.2490	4.96	3.98	Mg
4.725	2.015	.160	.40022	6.0030	7.01	5.62	Na
10.000	3.162	.000	.00316	.0710	.08	.07	K
4.761	2.030	.112	.33463	4.9870	5.83	4.67	Cl
4.810	2.040	.195	.44114	6.5970	7.71	6.18	SO <sub>4</sub>
4.775	2.032	.275	.52453	7.8480	9.17	7.35	PH
4.621	1.994	.069	.26274	3.9410	4.60	3.69	HCO <sub>3</sub>
-.842	.079	.078	.27845	.8630	1.28	.47	Ni
1.007	1.566	1.264	1.12421	1.1580	3.38	0.37	Cu
3.389	2.002	.006	.07613	.1180	0.30	.06	Zn
-1.561	-.276	.022	.14909	.4740	0.64	.25	Pb
1.847	1.257	.423	.65013	1.7400	3.20	1.10	BC
10.000	-3.162	.100	.31623	1.9000	2.00	1.00	Bi

Table 3-result of classification of sampling station based on benthic health

Station	Pollution	Biotic Coefficient	Biotic Index	Dominating Ecological Group	Benthic Community Health
1	Unpolluted	1.1	1	III	Transitional to pollution
2	Slightly	1.2	2	III	Transitional to pollution
3	Unpolluted	1.1	2	III	Transitional to pollution
4	Slightly	1.3	2	III	Transitional to pollution
5	Unpolluted	2.2	2	III	Transitional to pollution
6	Slightly	1.8	2	III	Transitional to pollution
7	Unpolluted	3.2	2	III	Transitional to pollution
8	Slightly	1.8	2	III	Transitional to pollution
9	Unpolluted	2.1	2	III	Transitional to pollution
10	Slightly	1.6	2	III	Transitional to pollution

Table 4- Hakanson classification of sediment pollution in sampling stations

$CF \geq 6$	$6 > CF \geq 3$	$3 > CF \geq 1$	$1 > CF >$	CF
Very high	high	Average	low	Sediment pollution

Table 5-result of sediment pollution in sampling stations

Station	UTM(X)	UTM(Y)	Elevation (m)	Pollution			
				Ni	Cu	Zn	Pb
1	390733.6	3778762	1656	Unpolluted	Slightly	Slightly	Slightly
2	390790.5	3780258	1656	Unpolluted	Slightly	Slightly	Slightly
3	390817.1	3781989	1658	Unpolluted	Unpolluted	Slightly	Slightly
4	389302	3785015	1652	Slightly	Slightly	Slightly	Slightly
5	388582.5	3787039	1653	Slightly	Slightly	Slightly	Slightly
6	393097.3	3789080	1651	Slightly	Unpolluted	Unpolluted	Slightly
7	389195	3790794	1652	Slightly	Slightly	Slightly	Slightly
8	396334.3	3787376	1658	Slightly	Slightly	Slightly	Slightly
9	399926.8	3786141	1660	Slightly	Unpolluted	Unpolluted	Slightly
10	395980.7	3781144	1656	Slightly	Unpolluted	Unpolluted	Slightly

## Figures

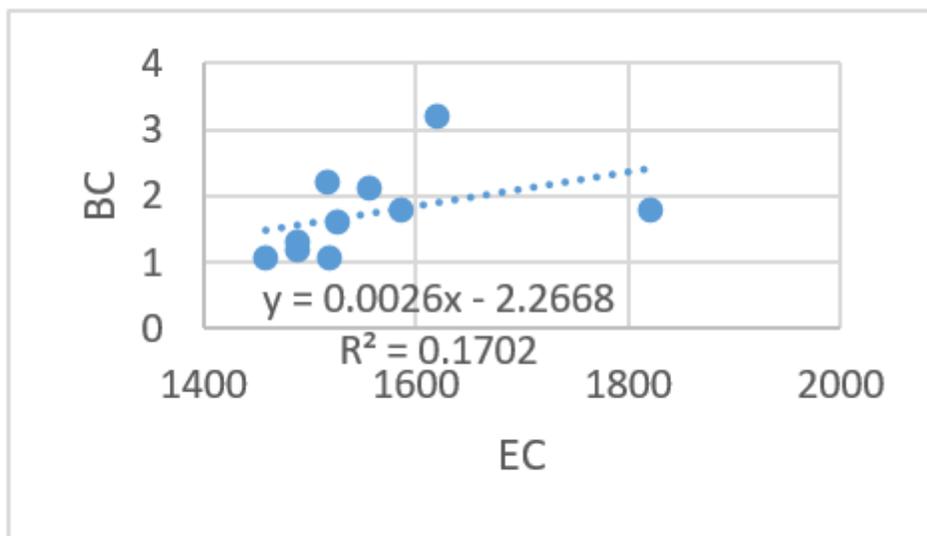
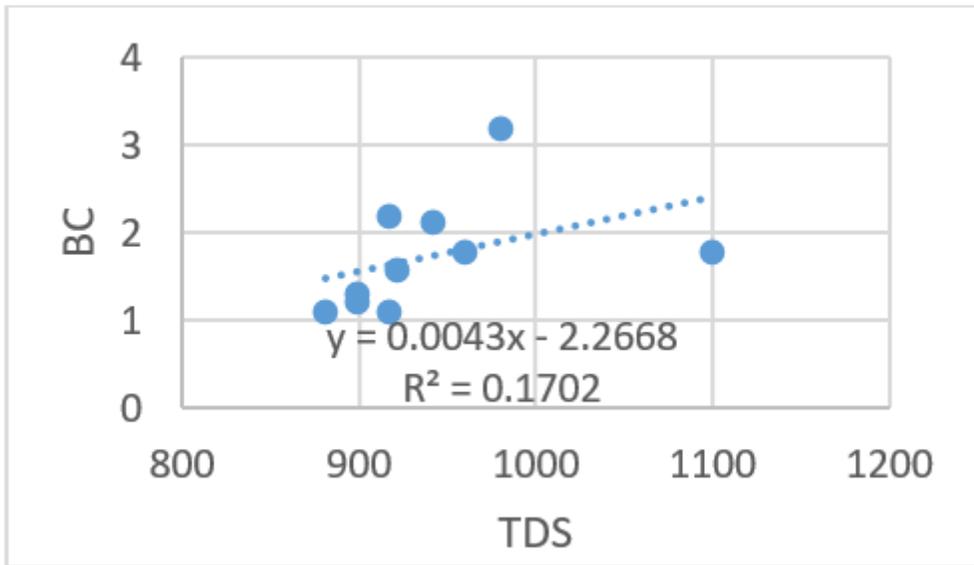


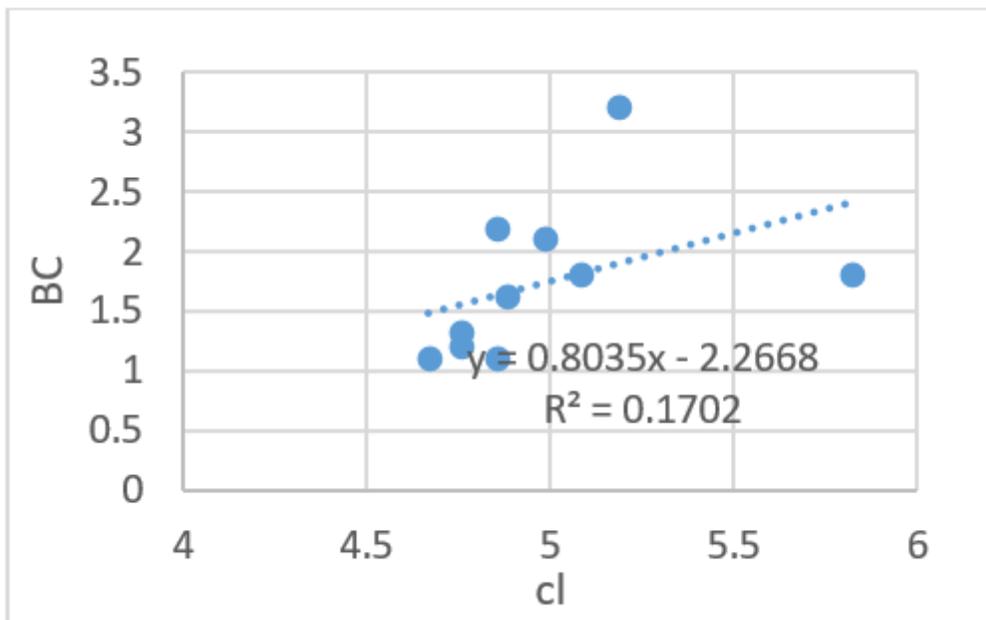
Figure 1

regression relationship between EC and BC



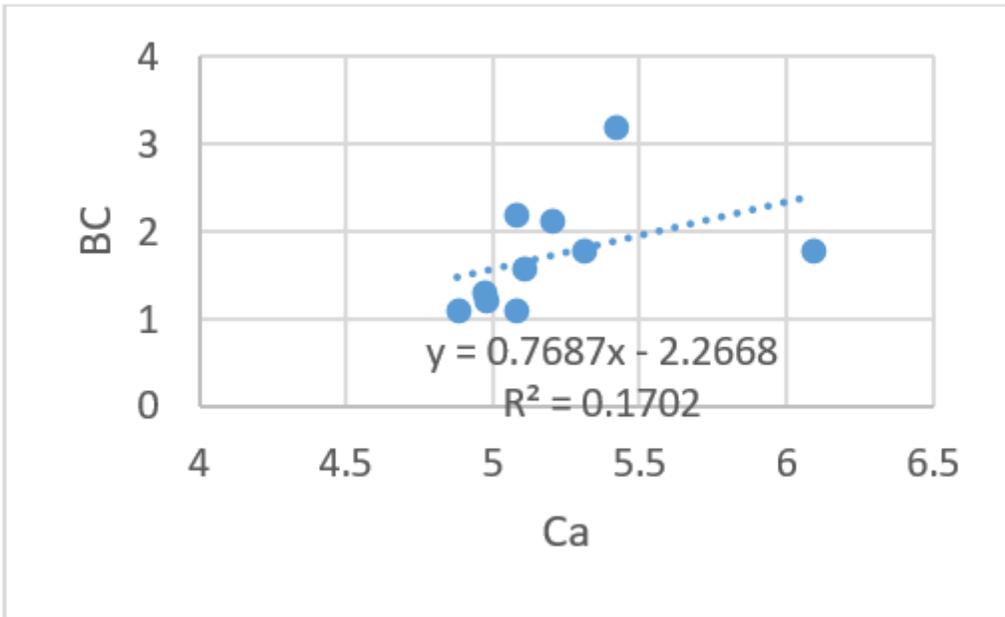
**Figure 2**

regression relationship between TDS and BC



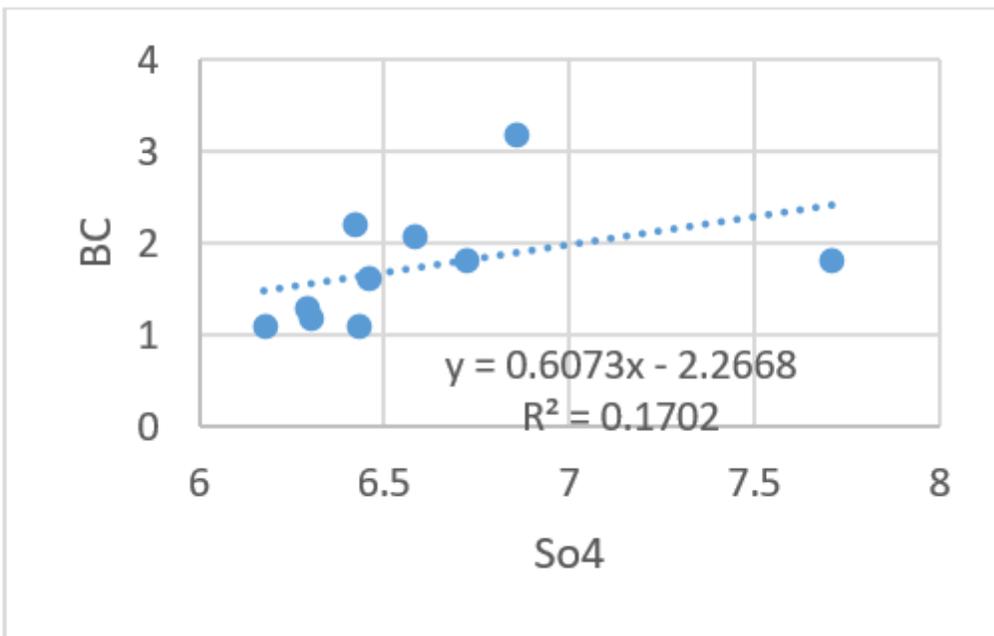
**Figure 3**

regression relationship between cl and BC



**Figure 4**

regression relationship between Ca and BC



**Figure 5**

regression relationship between so4 and BC

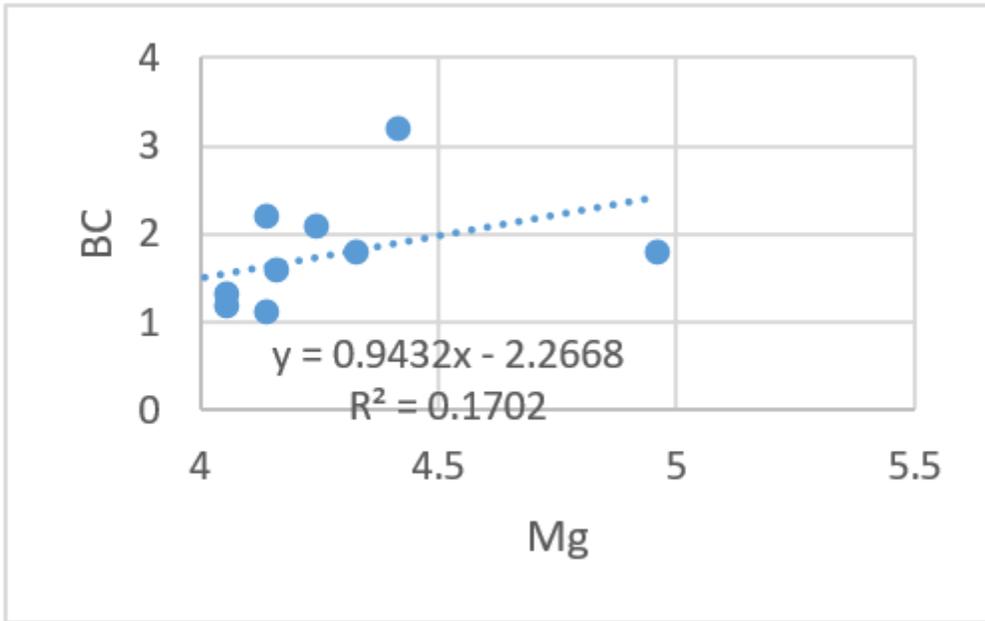


Figure 6

regression relationship between Mg and BC

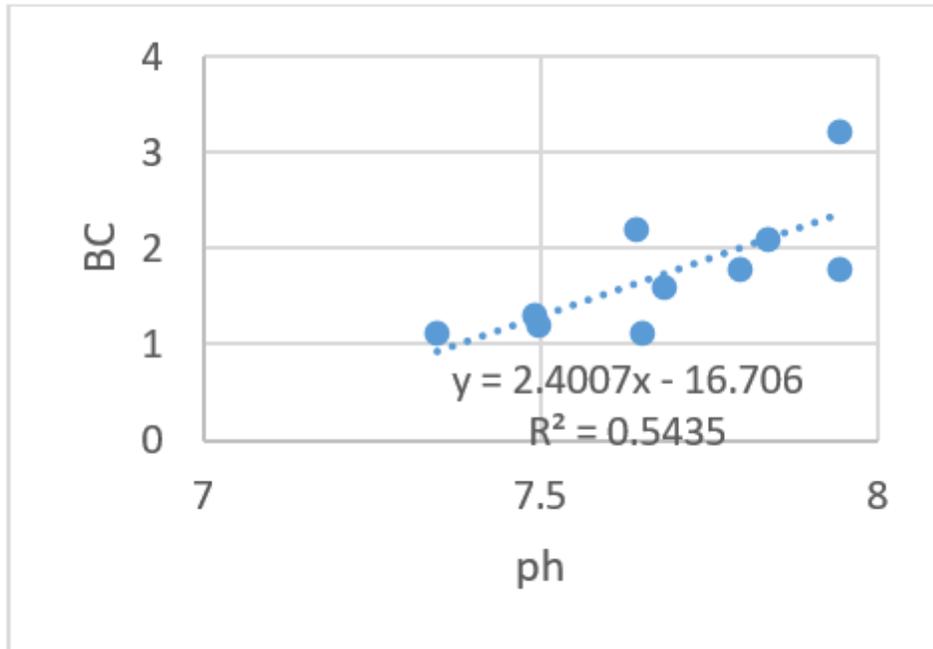
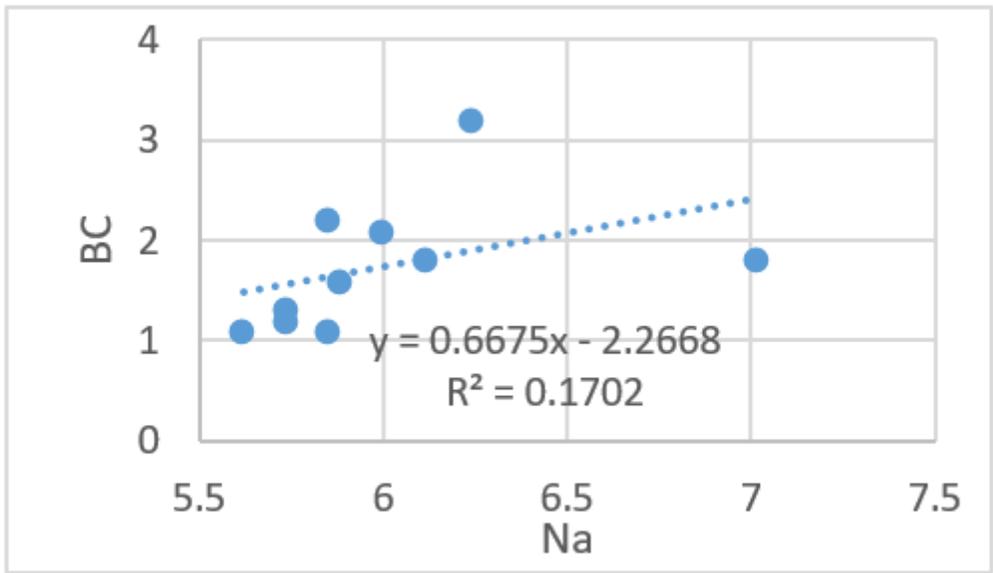


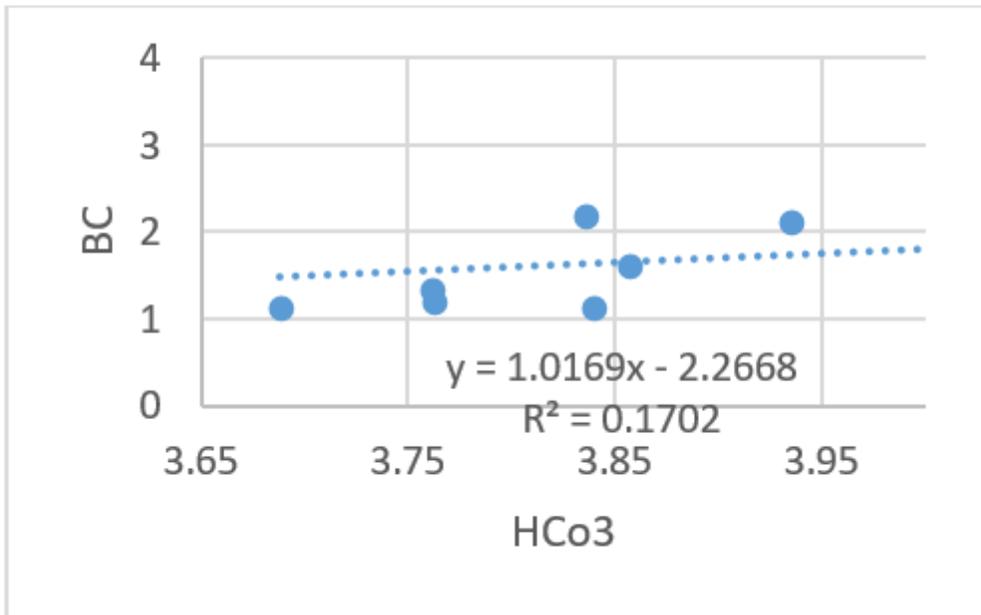
Figure 7

regression relationship between pH scale and BC



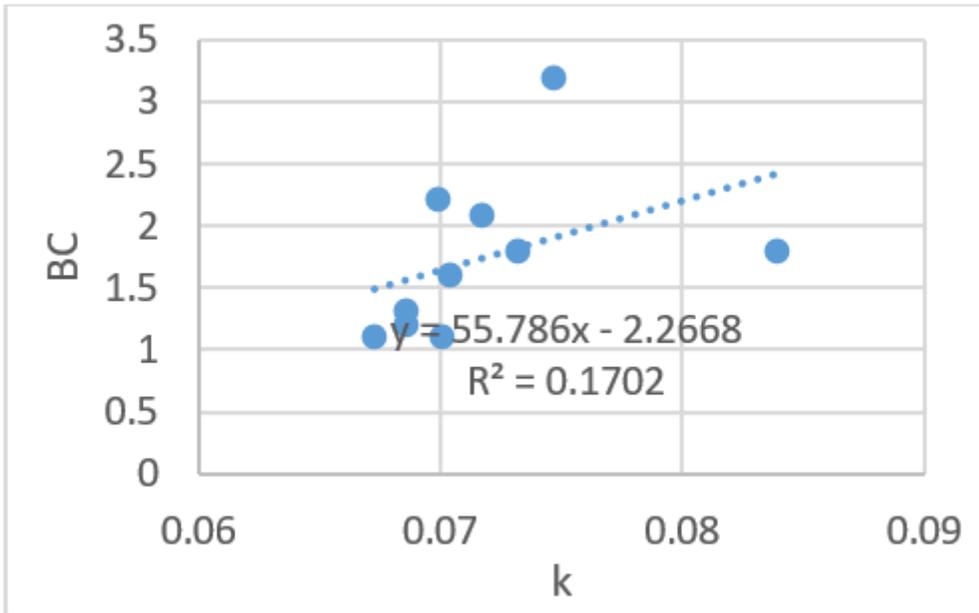
**Figure 8**

regression relationship between Na and BC



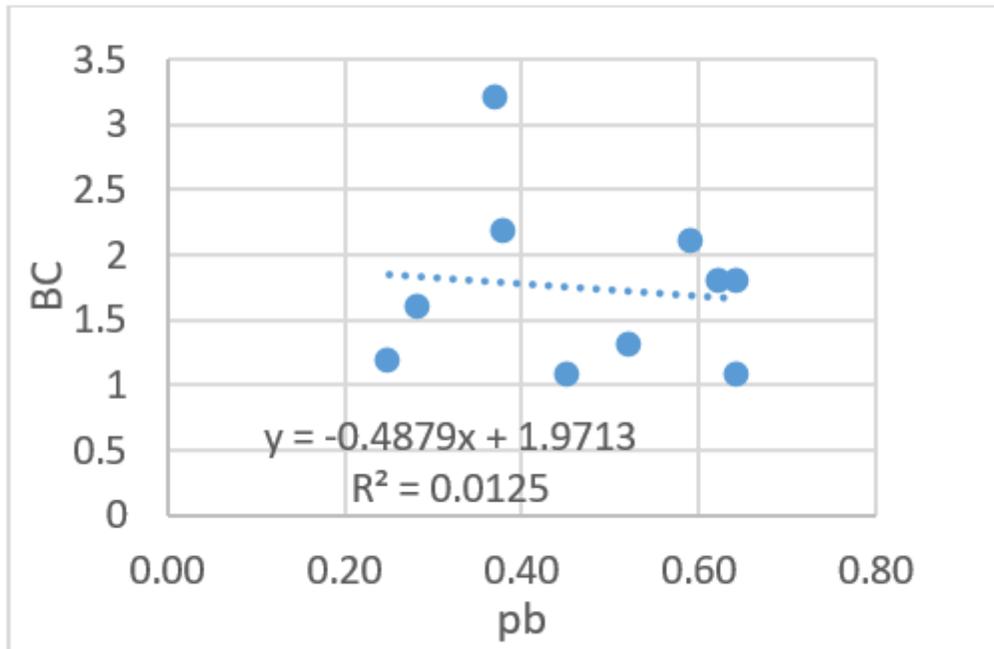
**Figure 9**

regression relationship between Hco3 and BC



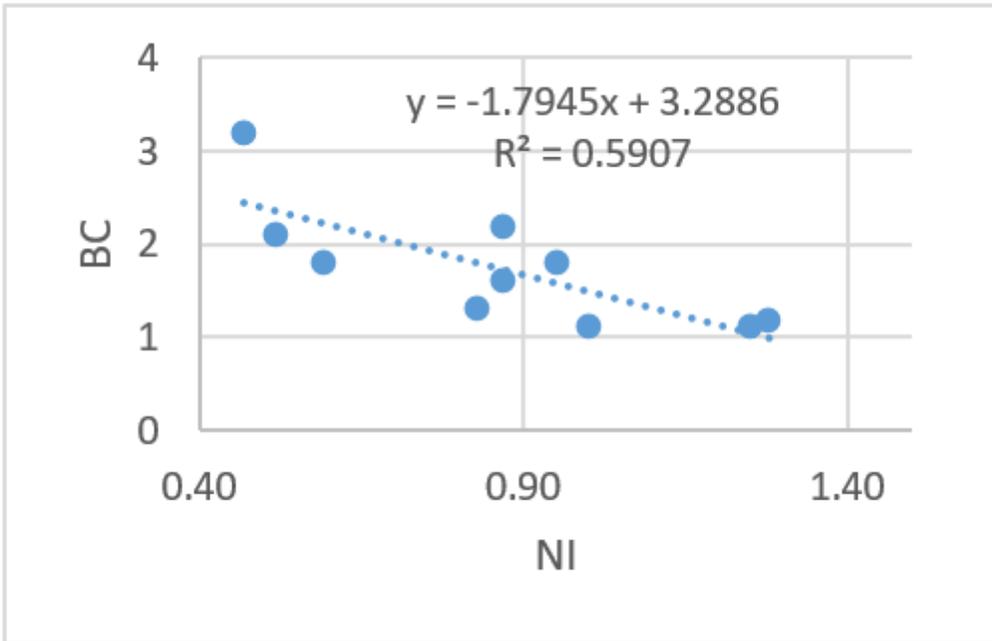
**Figure 10**

regression relationship between  $k$  and  $BC$



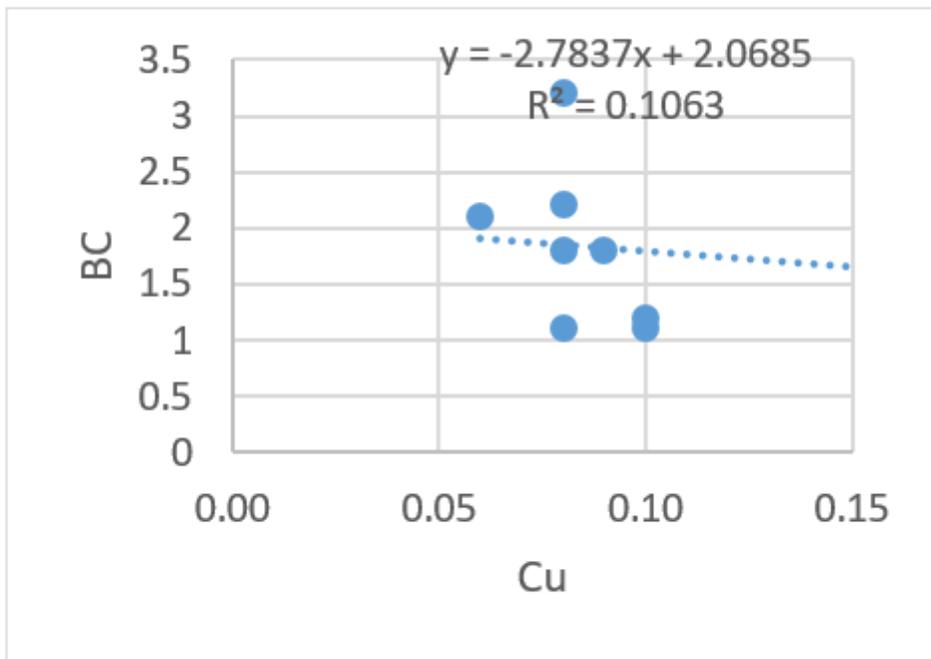
**Figure 11**

regression relationship between  $pb$  and  $BC$



**Figure 12**

regression relationship between Cu and BC



**Figure 13**

regression relationship between Cu and BC