Heavy Metal Concentration Analysis for Gastropods off the Red Sea, Egypt

By

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A thesis submitted in partial fulfillment of the requirements of the degree of

Bachelor of Arts

(Geology)

at

Gustavus Adolphus College

[2017]

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Under the supervision of Julie Bartley

Abstract:

Human activity has contributed harm to the environment, especially where human and animal life interact with practices such as mining. Mining releases pollutants into the atmosphere and environment which can cause negative side effects to the environment. One location that has had controversy over this issue is mining inland off the coast of the Red Sea in Egypt. There it's believed a lead and as well as a separate iron mine are releasing heavy metals that are affecting the nearby life such as the gastropods. Mining has been known to release the associated metals into the environment that are refined at the mine. Mining practices are known inland of the coast of the Red Sea, which have been to be a plausible source of the heavy metal contamination that is present in the sediment. To test the hypothesis that elevated metal concentrations in this area are impacting marine organisms, gastropods belonging to two species, were live collected from three localities along the coast of the Red Sea. Organic (soft tissue) and inorganic (shell) material from individual gastropods were separated, dissolved in nitric acid, and analyzed with an inductively-coupled plasma mass spectrometer (ICP-MS). The metals examined in this study include Mn, Fe, Cu, Zn, and Pb. This process calculated heavy metal concentrations to see whether or not these organisms are exposed to an environment with potentially toxic heavy metals along the coast of the Red Sea in Egypt. Gastropod samples generally showed higher concentrations of heavy metals, in both tissue and shell fractions, compared to uncontaminated gastropods from other locations, examined in previous studies. The common trend was highest metal concentrations in the northernmost locality of gastropod site collection, with lowest concentrations in the southernmost site of gastropod collection. Based on the data, the highest source of metal contamination is coming from the northernmost site of gastropod sample collection. The northernmost site is nearby a lead mine, which is causing the greatest pollution of heavy metals than the other plausible sources.

ACKNOWLEDGEMENTS

Julie Bartley- Served as Thesis Advisor, and also helped through almost every process throughout the study.

Jeff Jeremiason- Aided in running indictively coupled plasma mass- spectrometer (ICP-MS) for testing metal concentrations

Jim Welsh- Assited with understanding and interpreting articles of the geology of the area in study.

Laura Triplett- Assisted in writing of thesis.

El- Wekeil- Collected gastropod samples.

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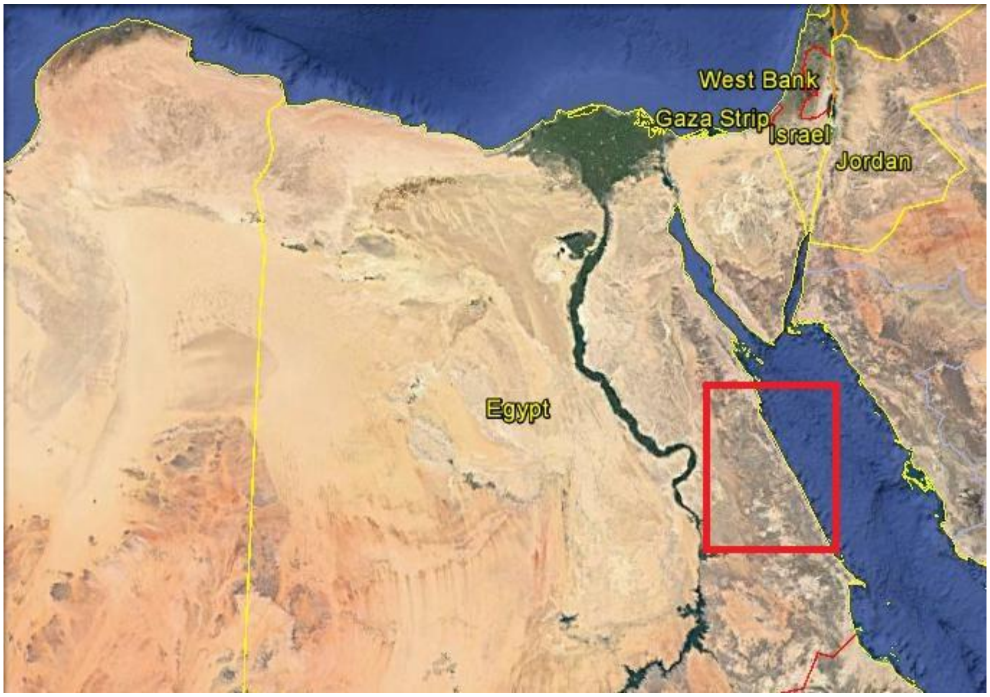
INTRODUCTION:

Areas with presence of heavy metal accumulation can have drastic effects on the environment including the organisms. Human activity throughout the world has resulted in mass levels of pollution and particularly in the Red Sea, high metal concentrations and other pollutants added from activities such as mining, harbor dredging, discharge of industrial effluents, urbanization, and over population (Abdelbaset et al, 2013). Areas with human activity are more prone to spread contamination through industrial practices. The Red Sea currently has mining activity, which according to El-Wekeil has been a plausible source of metal contamination off the coastline of the Red Sea (El-Wekeil et al, 2012). El-Wekeil tested metal concentrations in the sediment of several locations along the coastline of the Red Sea in Egypt and found high accumulations of metals in the sediment such as copper, iron, and manganese (El-Wekeil et al, 2012). One controversial mining source in the locality is a lead mine that is 6 km inland of the city Um Gheig. Previous studies have also indicated that this iron mine as had its ores studies and found high levels of pollution for zinc, lead, iron, and manganese (El-Anwar et al, 2013). There are rivers located next to this lead mine that were observed through Google Earth, which these downstream rivers could easily transport heavy metals from the mine to Um Gheig, the first site the gastropod samples were collected (El-Wekeil et al, 2012).

Heavy metals can accumulate in the tissues of organisms if they are exposed to metals in their environment, so gastropod shells and tissues are used as indicators if an area has heavy metal pollution based on the metal concentrations in the organisms (Bellotto et al, 2007). Studies in the past have been conducted which tested if organisms in a possibly tainted area are effected by heavy metal pollution by calculating element concentrations in shelled organisms such as gastropods (Kupekar et al, 2014). Although there have been studies regarding mineral concentrations of the coastal Red Sea, there has not been an analysis of the heavy metal concertation of gastropods in the area. For this study, collected gastropod samples were examined for concentrations of heavy metals with an Inductively Coupled Plasma-Mass Spectrometer (ICP-MS) to see whether or not these gastropods are living in an area that is contaminated with heavy metals.

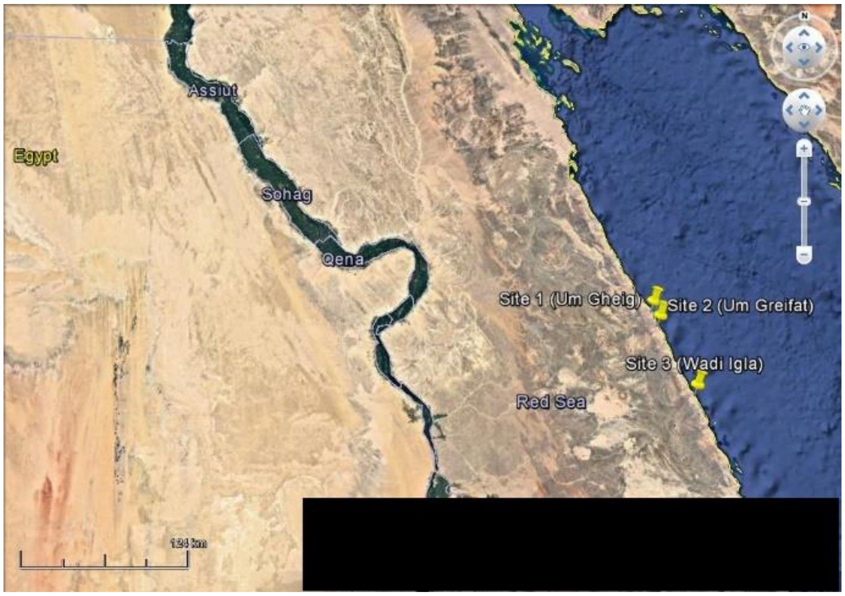
GEOLOGIC SETTING:

The area of study is located in northeastern Africa along the Red Sea in Egypt. The Red Sea was formed around twenty-five million years ago in the late Oligocene from a divergent rift boundary in present day Horn of Africa and the Arabian Peninsula. A divergent rift boundary is when two tectonic plates split or diverge away from each other, resulting in a sea body between the two plates like we see with the Red Sea. The current rifting in the Red Sea is part of the ongoing Gulf of Suez rift sequence which originated in the Late Oligocene to Early Miocene, which has resulted in the beach environment (El-Wekeil et al, 2012). This rift which resulted in the formation of the Red Sea became home to many organisms due to the new marine environment. This beach is home to many species of mollusks and gastropods such as *Echinolittorina subnodosauorium* and *Planaxis sulcatus*.

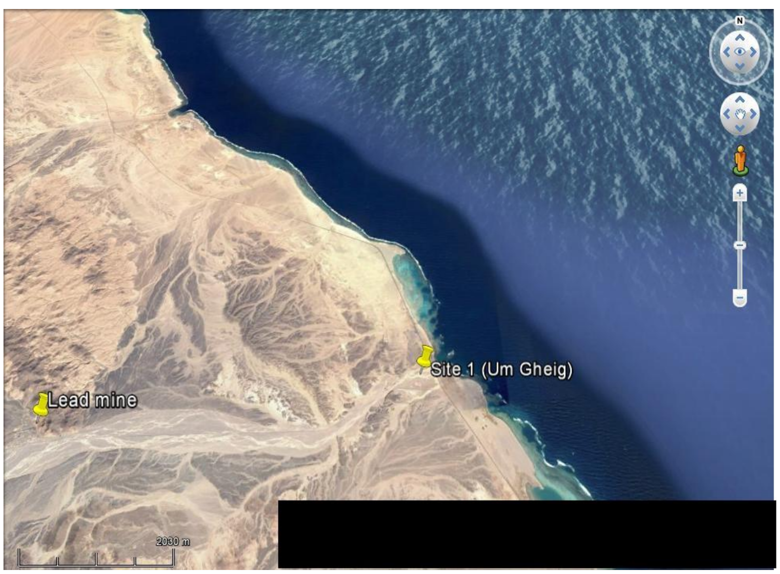


(Figure 1, area where gastropod samples *Echinolittorina Subnodosauorium* and *Planaxis Sulcatus* were collected. Latitude and longitudinal coordinates range from 25°9’28” N, 34° 51’19” E to 25° 44’6” N, 34 ° 34’53” E).

The area in red in the figure above gives us the precise area of the coastline that El-Wekeil collected the gastropod samples from. According to Google Earth, the latitude ranges from the southernmost location at 25 ° 09’27.69” N to the northern most at 25 °44’05.56” N, which the coastline extends approximately seventy kilometers. According to Google Earth, the longitude ranges from the west most location at 34 °34’52.99” E to the eastern most 34 °51’19.21" E. The three locations of our study consists of the areas Um Gheig (Site 1, 50 km S Quseir), Um Greifat (Site 2, 15 kilometers south of Um Gheig), and Wadi Igla (Site 3, 13 kilometers north of Mersa Alam).

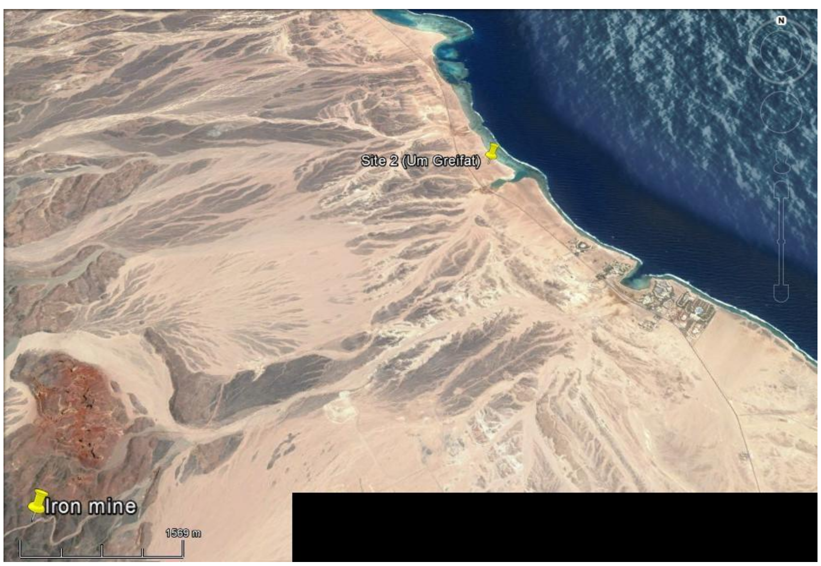


(Figure 2, the gastropod samples were collected off along the coast of the Red Sea from a 75 km stretch. This locality is experiencing the effects of the Gulf of Suez Rift between the Arabian Peninsula and the Horn of Africa).



(Figure 3, map of proximity from site 2 (Um Gheig) and the lead mine which is located 6 km inland from the site of sample collection).

There is a lead mine that is 6 kilometers west of the Um Gheig locality. The lead mine accumulated its lead from hydrothermal vents that transported lead and zinc from its Precambrian basement to the surface (Abour El-Anwar et al, 2013). Similar lead- zinc ores are present throughout the area, and since there is presence of rivers that flow downstream, it is possible the lead and zinc ores could travel downstream to the coastline. Rivers that flow downstream to the coastlines could potentially carry heavy metals that would potentially reach the area where the gastropods live. The next locality that El-Wekeil collected gastropods from is in Um Greifat. Um Greifat is approximately 15 kilometers south of site 1 of Um Gheig (El-Wekeil et al, 2012). There is also an iron mine that is 10 kilometers west of the Um Greifat locality which El-Wekeil has been noted as a controversial and plausible heavy metal contamination source (Gaber, 2012). The nature of the iron ores consists of yellow and red ochre which is essentially a hematitic clay resulted from chemical weathering (Gaber, 2012).



(Figure 4, map of proximity from site 2 (Um Greifat) and the iron mine which is located 15 kilometers south of the northernmost Um Gheig).

Our third source of gastropod collection is in the city of Wadi Lagi, which is also located along the coastline and is 10 kilometers east off of heavy presence of lead zinc ores.

(Figure 5, map of proximity from site 3 (Wadi Igla) and heavy lead-zinc ores.)

Given the current beach environment and geology, it is definitely possible that pollutants from the mines could travel to the coastlines and harm the organisms in this area. The uppermost sediment contains predominately sand like any other beach environment (El-Wekeil et al, 2012). There is presence of lead and zinc within the uppermost sediment which originated in a mineralization process in the Precambrian. Hydrothermal vents carried the lead and zinc that was in Precambrian basement rock to the sandy surface by hydrothermal vents (El Anwar et al, 2013). The uppermost sediment layer along the coast of the Red Sea is predominately sandstone; a porous and permeable rock which could potentially hold toxic heavy metals in its pore space which can be exposed to the surface (El-Wekeil et al, 2012). The Red Sea's oceanic current is based on the direction of the wind, which drives the current northward in the winter months, and the current moves southward in the summer months. Based on the direction of the current going north and south, it is possible for heavy metals to spread to different localities due to the direction of the current of the Red Sea, with a net transport of sediment transport to the north (2012). This nature of the ocean current means that if there is a high amount of heavy metal concentrations in the southernmost site of Wadi Igla, the ocean current could play a role in carrying the metals northward.

METHODS:

The samples consisted of living gastropods collected in 2012 by El-Wekeil from the three locations along the coast of the Red Sea in Egypt described above. Two species of gastropods were collected and analyzed in this study, *Planaxis sulcatus* and *Echinolittorina subnodosauorium*. Following collection, gastropods were separated by species and stored in dry conditions in plastic sample bags. The ultimate goal was for the hard shell (inorganic) parts and soft tissue (organic) parts to be measured in heavy metal concentration by an Inductively Coupled Plasma- Mass Spectrometer (ICP-MS) after being dissolved in nitric acid. The heavy metals in focus included: manganese (Mn), iron (Fe), copper (Cu), zinc (Zn), and lead (Pb). The metals in focus were based off of the findings of metals in the sediments of along the coastline of the Red Sea from previous work. Empty 15 mL vials were weighed and crushed gastropod samples were placed in vials. The initial attempt to crush and separate shells from tissues consisted of using a glass rod. The glass rod method did not work so the samples were crushed with a mortar and pestle, then placed in the empty 15 mL vials to be weighed. 2 mL of glacial acetic acid (28.5 mL 5 M acetic acid per 100 mL of mixed acid and milli Q water) was added to the crushed gastropod samples so the inorganic parts would dissolve into a liquid and separate from the organic components. After fully dissolved and centrifuged, the liquid inorganic material was pipetted off into new empty 15 mL vials and were labeled. 20 microliters of the dissolved inorganic material were pipetted off into a new empty 15 mL vial. Then 2 mL of 2% spiked Nitric Acid was added to the 20 micro liters of inorganic liquids. The solution was left overnight to react. The solutions were then centrifuged, and then the vials were filled with 10 mL of 2% spiked nitric acid. The vials were then shaken and were ran by the ICP-MS.

The remaining organic material in the original vials were rinsed with milli Q water 3-5 times so the acetic smell would go away. Once dried after being left overnight in the oven, the organic material weight was recorded. Then a 2mL solution of 30% hydrogen peroxide was added to the organic material so that it would dissolve. The samples were placed in a water bath set at 40°C so that the organic samples would dissolve faster with the addition of heat. Some of the Organic samples needed more addition of hydrogen peroxide and time to dissolve depending on the size of the sample. Originally, an initial set of samples were dissolved in sodium hypochlorite, however, the samples became contaminated and were not able to be used for the remainder of the study; and the hydrogen peroxide method was successful. After dissolving in the water bath, the vial lids were taken off and placed in the oven to dry. After drying, the vials and the remaining organic residue were weighed. After being weighed, 10 mL of nitric acid was added to the organic samples and were ran by the ICP-MS.

An additional method was performed on a set of gastropod samples for measuring concentrations in the inorganic parts- loss on ignition. Small crucibles were cleaned and weighed. Then one shell from each species was placed in one of each of the crucibles and was also weighed with the shell. The shells in the crucibles were placed in a furnace at 550 degrees Celsius to vaporize the organic material. After the organic material was vaporized and there was only hard inorganic material remaining. The shells were then crushed and placed in to 1.5 mL vials and weighed. The crushed inorganic samples were measured out so 1 mg was placed into a new 15 mL vial. Then 2 mL of 2% spiked Nitric Acid was added to the crushed 1 mg shells. The samples were vortexed then left overnight to react. The samples were then centrifuged for ten minutes. After centrifuged, the vials were filled with the 2% spiked Nitric Acid so that there were 10 milliliters of fluid in the vial. The vials were then shaken and were ran by the ICP-MS.

RESULTS:

The metals that were focused on for the study consisted of manganese (Mn), iron (Fe), Copper (Cu), Zinc (Zn),), and lead (Pb). Metals were measured in parts per million (ppm).

Inorganic Material

29 gastropod samples were used in total for the measurement of metal accumulation inorganic material. The following three tables show the total results from all 29 gastropod samples for inorganic material. The samples with “P” in their name are from the species *Planaxis sulcatus*, while the samples with “E” in their name are from the species *Echinolittorina subnodosauorium*.

(Table 1, metal concentrations in ppm for manganese, iron, copper, zinc, and lead in inorganic materials from Um Gheig. The samples with "P" in their name are from the species *Planaxis sulcatus*, while the samples with "E" in their name are from the species *Echinolittorina subnodosauorium*)

Um Gheig	50P-1I	50P-2I	50P-3I	50E-1I	50E-2I	50P-4I	50P-5I	50P-6I	50E-4I	50E-5I	50E-6I
Mn (ppm)	17.86	17.1	13.7	20.26	7.059	0	0	0	0	0	0
Fe (ppm)	78.01	75.69	85.59	193	51.91	0	0	0	0	0	0
Cu (ppm)	10.64	9.707	7.382	8.832	3.843	4.711	3.468	4.779	0	0.03911	0
Zn (ppm	51.28	40.53	42.24	82.82	18.68	8.969	9.109	9.311	0	0	0
Pb (ppm)	6.111	5.258	14.09	10.34	6.883	0	0	0	0	0	0

The range for magnesium concentrations for *Echinolittorina subnodosauorium* was 0 – 20.26 ppm, and the *Planaxis sulcatus* ranged from 0 - 17.86 ppm.

The range for iron concentrations for *Echinolittorina subnodosauorium* was 0 – 193 ppm, and the *Planaxis sulcatus* ranged from 0 - 85.59 ppm.

The range for copper concentrations for *Echinolittorina subnodosauorium* was 0 - 8.832 ppm, and the *Planaxis sulcatus* ranged from 3.468 – 10.64 ppm.

The range for zinc concentrations for *Echinolittorina subnodosauorium* was 0 – 82.82 ppm, and the *Planaxis sulcatus* ranged from 8.969 - 51.28 ppm.

The range for lead concentrations for *Echinolittorina subnodosauorium* was 0 – 10.34 ppm, and the *Planaxis sulcatus* ranged from 0 - 6.883 ppm.

(Table 2, metal concentrations in ppm for manganese, iron, copper, zinc, and lead in inorganic materials from Um Greifat. The samples with “P” in their name are from the species *Planaxis sulcatus*, while the samples with “E” in their name are from the species *Echinolittorina subnodosauorium*)

Um Greifat	15P-2I	15E-1I	15E-2I	15P-4I	15P-5I	15P-6I	15E-4I	15E-5I	15E-6I
Mn (ppm)	9.79	25.44	8.939	0	0	0	0	0	0
Fe (ppm)	53.54	400.9	150.2	0	0	0	0	0	0
Cu (ppm)	6.415	10.18	3.414	2.394	5.095	3.201	1.383	1.794	31.07
Zn (ppm	22.8	46.34	34.08	4.878	14.5	8.333	1.303	2.727	6.102
Pb (ppm)	4.989	9.158	8.155	0	0	0	0	0	0

The range for magnesium concentrations for *Echinolittorina subnodosauorium* was 0 – 25.44 ppm, and the *Planaxis sulcatus* ranged from 0 – 9.79 ppm.

The range for iron concentrations for *Echinolittorina subnodosauorium* was 0 – 400.9 ppm, and the *Planaxis sulcatus* ranged from 0 - 53.54ppm.

The range for copper concentrations for *Echinolittorina subnodosauorium* was 1.383 – 31.07 ppm, and the *Planaxis sulcatus* ranged from 2.394 – 6.415 ppm.

The range for zinc concentrations for *Echinolittorina subnodosauorium* was 1.303 – 46.34 ppm, and the *Planaxis sulcatus* ranged from 4.878 – 22.8 ppm.

The range for lead concentrations for *Echinolittorina subnodosauorium* was 0 – 9.158 ppm, and the *Planaxis sulcatus* ranged from 0 - 4.989 ppm.

(Table 3, metal concentrations in ppm for manganese, iron, copper, zinc, and lead in inorganic materials from Wadi Igla. The samples with "P" in their name are from the species *Planaxis sulcatus*, while the samples with "E" in their name are from the species *Echinolittorina subnodosauorium*)

Wadi Igla	13P-1I	13P-2I	13E-1I	13P-4I	13P-5I	13P-6I	13E-4I	13E-5I	13E-6I
Mn (ppm)	18.86	26.52	15.19	0	0	0	0	0	0
Fe (ppm)	127.8	63.73	77.82	0	0	0	0	0	0
Cu (ppm)	5.629	3.523	4.182	0	0.13	0	0	0	0
Zn (ppm	39.24	28.39	42.8	0	0	0	0	0	0
Pb (ppm)	6.108	6.898	5.292	0	0	0	0	0	0

The range for magnesium concentrations for *Echinolittorina subnodosauorium* was 0 – 15.19 ppm, and the *Planaxis sulcatus* ranged from 0 - 26.52 ppm.

The range for iron concentrations for *Echinolittorina subnodosauorium* was 0 – 77.82 ppm, and the *Planaxis sulcatus* ranged from 0 - 127.8 ppm.

The range for copper concentrations for *Echinolittorina subnodosauorium* was 0 – 4.182 ppm, and the *Planaxis sulcatus* ranged from 0 - 5.629 ppm.

The range for zinc concentrations for *Echinolittorina subnodosauorium* was 0 – 42.8 ppm, and the *Planaxis sulcatus* ranged from 0 39.24 ppm.

The range for lead concentrations for *Echinolittorina subnodosauorium* was 0 – 5.292ppm, and the *Planaxis sulcatus* ranged from 0 - 6.898 ppm.

Organic Material

4 gastropod samples were used in total for the measurement of metal accumulation organic material due to contamination from attempted. Organic material was only collected from the species *Echinolittorina subnodosauorium*. The following three tables show the total results from all 4 gastropod samples for organic material.

(Table 4, concentration of heavy metals for manganese, iron, copper, zinc, and lead in Um Gheig organic samples)

Um Gheig	50E-6
Mn (ppm)	10.69
Fe (ppm)	370.2
Cu (ppm)	3.965
Zn (ppm)	0
Pb (ppm)	9.636

The manganese concentration was 10.69 ppm. The iron concentration was 370.2 ppm. The copper concentration was 3.965 ppm. No concentration of zinc was found. The lead concentration was 9.636 ppm.

(Table 5, concentration of heavy metals for manganese, iron, copper, zinc, and lead in Um Greifat organic samples)

Um Greifat	15 E-6
Mn (ppm)	0
Fe (ppm)	487.8
Cu (ppm)	35.1
Zn (ppm)	0
Pb (ppm)	0

No concentration of manganese was found. The iron concentration was 487.8 ppm. The copper concentration was 35.1 ppm. No concentration of zinc was found. No concentration of lead was found.

(Table 6, concentration of heavy metals for manganese, iron, copper, zinc, and lead in Wadi Igla organic samples)

Wadi Igla	13 E-4	13 E-6
Mn (ppm)	0	0
Fe (ppm)	64.78	22.04
Cu (ppm)	0.982	1.216
Zn (ppm)	0.16	0.613
Pb (ppm)	0.053	0

No concentration of manganese was found. The range for iron concentrations was 22.04 – 64.78 ppm. The range for copper concentrations was 0.982 -1.216 ppm. The range for zinc concentrations was 0.16 – 0.613 ppm. The range for lead concentrations was 0 – 0.053 ppm.

Discussion:

The data collected was organized spatially from each locality and was also examined in comparison to uncontaminated gastropod sample data. Data that was collected was compared to results from previous studies that examined metal concentrations for manganese, iron, copper, zinc, and lead at uncontaminated sites. The following two tables shows concentrations of heavy metals for gastropods without contamination from previous studies. The uncontaminated gastropods were collected from Iran and India as follows.

(Table 7, data concentrations in ppm for lead, zinc, and copper for uncontaminated gastropod samples of *Cerathideacingulata*, collected in the intertidal zone of Hormozgan Province in Iran Manavi, 2013)

Station	**Sample- *Cerathideacingulata***	**Pb**	**Zn**	**Cu**
Park in Bandar Abbas	Tissue	ND	0.183	0.015
	Shell	ND	0.008	0.005
Haghani Terminus in Bandar Abbas	Tissue	ND	0.315	0.024
	Shell	ND	0.07	0.001
Bandar Moallem	Tissue	ND	0.005	0.003
	Shell	0.001	ND	ND
Bandar Lengeh	Tissue	0.001	0.27	0.113
	Shell	0.001	0.07	0.03

(Table 8, gastropod samples from Ambekar et al displaying heavy metal concentrations for uncontaminated *Nerita oryzarum*, collected in Maharashtra India, 2013)

Location		**Mn**	**Fe**	**Cu**	**Zn**	**Pb**
TAPS 1&2	Shell	0.12	0.99	0.17	ND	ND
	Tissue	0.59	3.77	0.99	1.07	ND
TAPS 3&4	Shell	0.24	0.94	0.18	ND	0.06
	Tissue	0.36	3.26	1.03	1.03	ND
LightHouse	Shell	0.26	0.96	0.16	ND	0.04
	Tissue	0.38	3.14	1.29	1.07	ND
Popharan	Shell	0.37	0.98	0.22	ND	0.05
	Tissue	0.59	4.57	0.43	1.24	ND
Varor	Shell	0.16	0.98	0.11	ND	ND
	Tissue	0.64	3.16	0.93	1.15	ND
Nandgaon	Shell	0.47	1.03	0.32	ND	0.11
	Tissue	0.78	3.15	1.37	1.42	ND

These uncontaminated samples show relatively small amounts of heavy metal accumulation. The following tables give the average concentration of heavy metal accumulation for the focused metals for the inorganic and organic material as follows. Average metal concentrations of both combined species were calculated. The cells highlighted red indicate higher concentrations of heavy metals in ppm compared to the uncontaminated samples from previous work.

(Table 9, average heavy metal concentration for the 29 inorganic samples by location. the cells highlighted red indicate concentrations above uncontaminated samples)

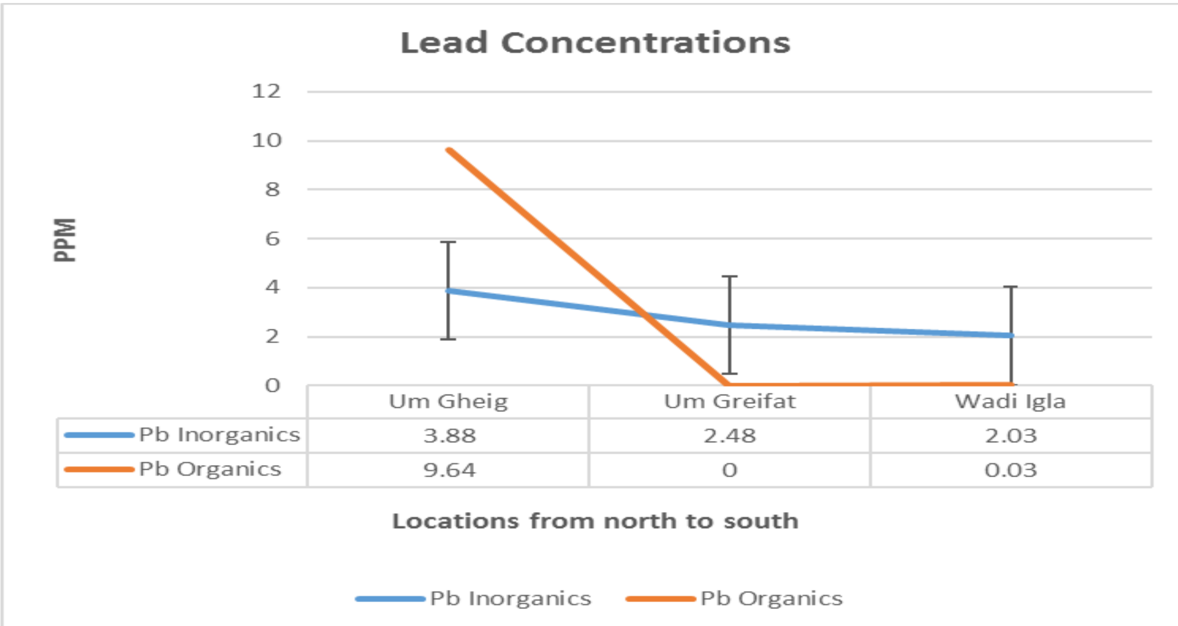
Metal Average ppm	**Number of Samples**	**Mn**	**Fe**	**Cu**	**Zn**	**Pb**
Um Gheig	11	6.91	44.02	4.85	23.9	3.88
Um Greifat	9	4.91	67.18	7.22	15.67	2.48
Wadi Igla	9	6.73	29.92	1.5	12.27	2.03
Average	29	6.18	47.04	4.52	17.28	2.8

(Table 10, average heavy metal concentration for the 4 organic samples by location. the cells highlighted red indicate concentrations above uncontaminated samples)

Metal Average ppm	Number of Samples	Mn	Fe	Cu	Zn	Pb
Um Gheig	1	10.7	370.2	3.97	0	9.64
Um Greifat	1	0	487.8	35.1	0	0
Wadi Igla	2	0	43.41	1.1	0.386	0.03
Average	4	3.56	300.5	13.4	0.129	3.22

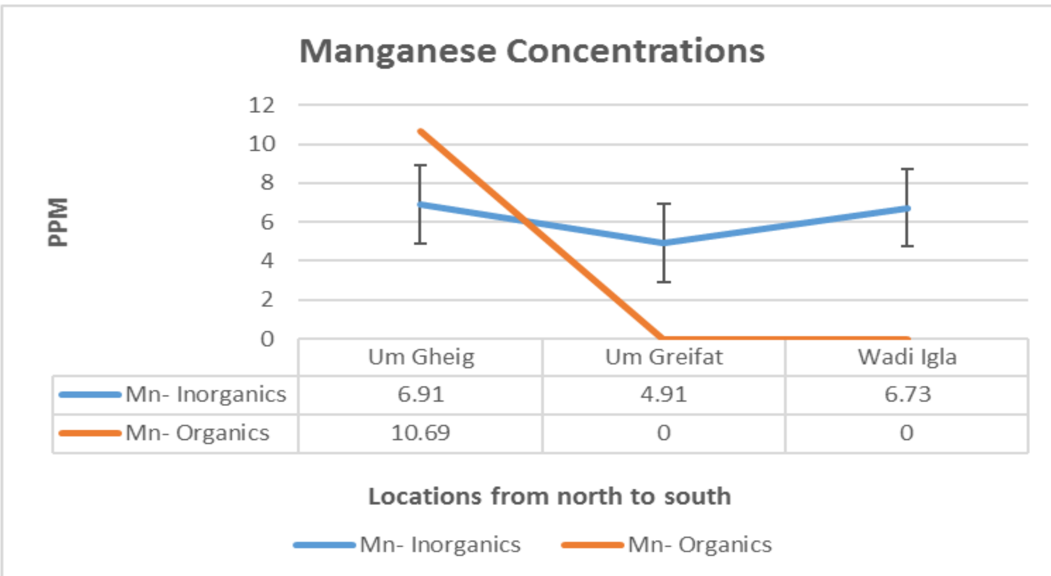
Our results have much higher concentrations of the heavy metals analyzed compared to gastropod samples studied in uncontaminated environments (Ambekar et al, 2013) (Manavi, 2013). With the exception of the concentration of zinc for organic components, all other metals were detected in concentrations higher than in gastropods collected in uncontaminated areas. The most common spatial pattern in metal concentration shows highest heavy metal concentrations in the northern locality Um Gheig and lower concentrations in the southern localities. The following order of metals discussed below is based off of accumulation averages per location.

(Table 11, average concentration in ppm of lead present in gastropods in each location from north to south. Inorganic material concentrations are in blue, and organic material concentrations are in orange)



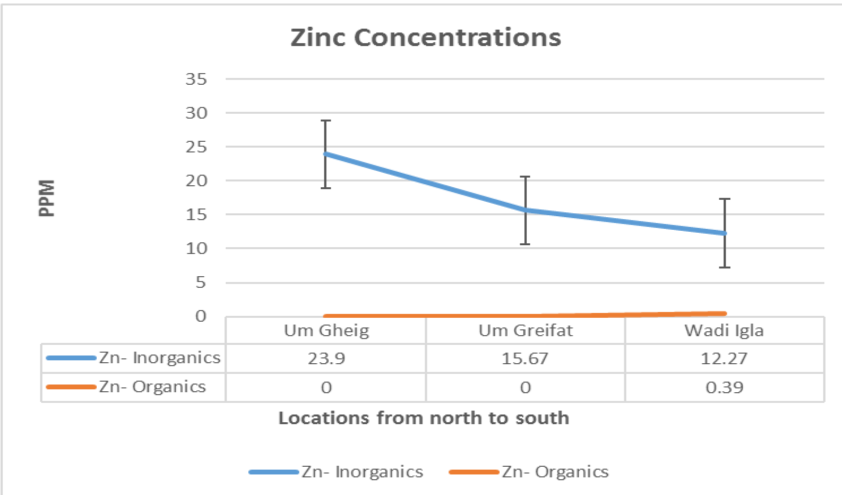
The uncontaminated gastropod samples from the previous studies ranged from 0.001 – 0.11 ppm in lead concentration. The inorganic material at all three locations had much higher lead accumulations than the uncontaminated samples, as shown in the graph. The organic material had higher accumulations of lead than uncontaminated gastropods at the northernmost site Um Gheig, but was smaller or equal in the two southern locations. The highest amounts of lead concentrations found in gastropod shells and tissues was found at Um Gheig. Um Gheig is the site closest to the lead mine from lead- zinc ores. Lead could have potentially travelled from the mining area to the coastline where the gastropods live. The trend for inorganic components shows highest amounts of contamination in the north, and decreases further south. The spatial trend has the highest accumulations of lead in the north, and the least in the south.

(Table 12, average concentration in ppm of manganese present in gastropods in each location from north to south. Inorganic material concentrations are in blue, and organic material concentrations are in orange)



The uncontaminated gastropod samples from previous studies had a range of manganese from 0.12 – 0.78 ppm. The inorganic material at all three locations had much higher manganese accumulations than the uncontaminated samples, as shown in the graph. The organic material had higher accumulations than uncontaminated gastropods of manganese at the northernmost site Um Gheig, but was smaller in the two southern locations. The highest manganese concentrations were found at the Um Gheig site for both inorganics and organics. The manganese concentration in inorganics at Um Gheig had a similar average compared to the Wadi Igla. This is most likely due to being near areas with similar geochemistry from the lead- zinc ores (El- Anwar et al, 2013). However, the only organic components that detected manganese was only found in Um Gheig.

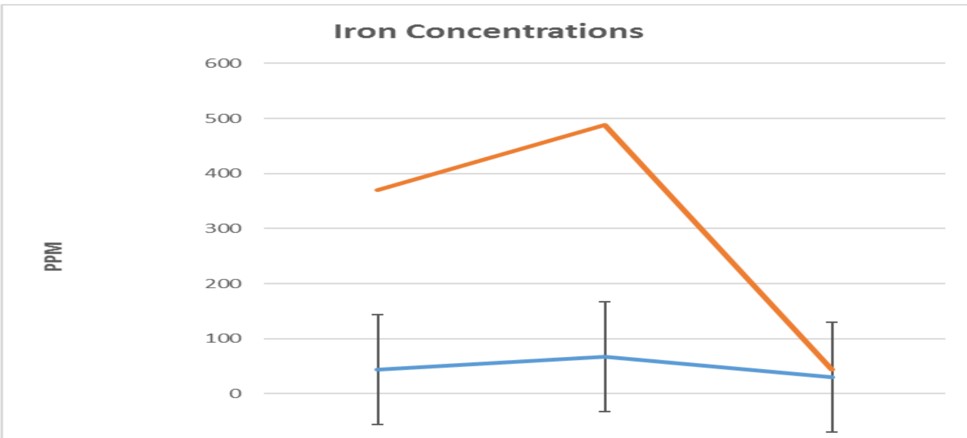
(Table 13, average concentration in ppm of zinc present in gastropods in each location from north to south. Inorganic material concentrations are in blue, and organic material concentrations are in orange)



The uncontaminated gastropod samples from previous studies had a range of zinc from 0.005 – 1.42 ppm. The inorganic material at all three locations had much higher zinc accumulations than the uncontaminated samples, as shown in the graph. Organic material did not accumulate zinc higher than the zinc concentrations in the uncontaminated samples. The highest zinc concentrations were found at Um Gheig for inorganics, and Wadi Igla for organics. Organic samples did not detect zinc except for samples collected at Wadi, which only detected a small amount of zinc. Inorganic sample averages exceeded the concentration of zinc compared to uncontaminated gastropods. The highest amount of zinc in inorganics was found at Um Gheig, the site closest to the lead mining from the lead- zinc ores. The lowest amount of zinc in inorganics was found at Wadi Igla, the site furthest away from the lead mine, showing a distinct trend of highest contamination in the north with the lowest in the south.

The other trend that appeared within our data consisted of highest concentrations of metals detected in site 2 Um Greifat, which was the case for iron and copper.

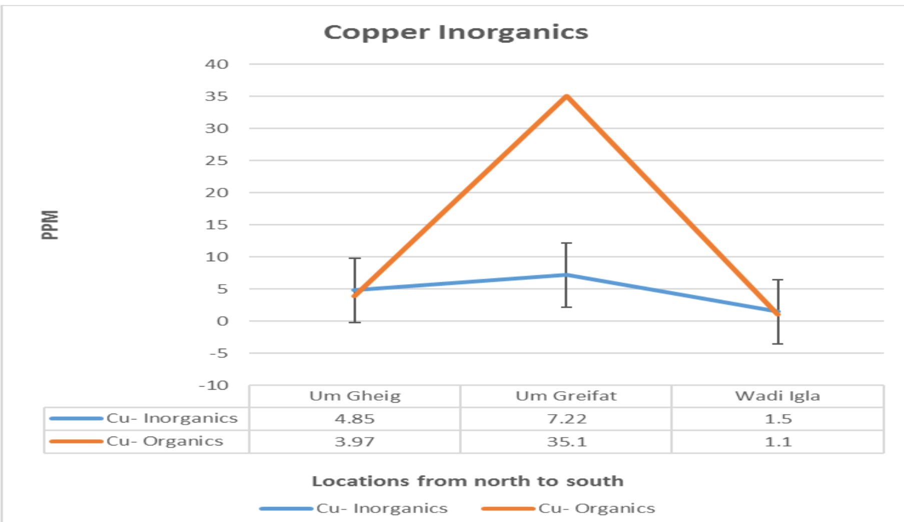
(Table 14, average concentration in ppm of iron present in gastropods in each location from north to south. Inorganic material concentrations are in blue, and organic material concentrations are in orange)



	Um Gheig	Um Greifat	Wadi Igla
Fe- Inorganics	44.02	67.18	29.92
Fe- Organics	370.22	487.85	43.41

The uncontaminated gastropod samples from previous studies had a range of iron from 0.94 – 4.57 ppm. The inorganic material at all three locations had much higher iron accumulations than the uncontaminated samples, as shown in the graph. Organic material also accumulated much higher iron concentrations than the uncontaminated samples. The highest accumulations of iron were detected at Um Greifat. There's no surprise that the highest amount of iron was found at Um Greifat. Um Greifat is an iron mine with yellow and red ochre, which is essentially hematitic regolith. The weathered iron from the rock could travel downstream from the iron mine to reach the coastline where the gastropods live. Um Gheig detected more concentrations of iron for inorganics and inorganics than Wadi Igla. This could be due to the proximity of the localities, Um Gheig is only approximately 12 kilometers north of Um Greifat, whereas Wadi Igla is 58.5 kilometers south of Um Greifat. Due to the predominately northward ocean current, iron could also spread from Um Greifat northward via ocean current to reach Um Gheig, giving Um Gheig more iron concentration than Wadi Igla.

(Table 15, average concentration in ppm of copper present in gastropods in each location from north to south. Inorganic material concentrations are in blue, and organic material concentrations are in orange)



The uncontaminated gastropod samples from previous studies had a range of copper from 0.001 – 1.37 ppm. The inorganic material the two north locations had much higher copper accumulations than the uncontaminated samples, whereas Wadi Igla experienced similar concentrations to the uncontaminated samples. Organic material also accumulated much higher copper concentrations in the two north locations than the uncontaminated samples, with again Wadi Igla having concentrations of copper similar to uncontaminated gastropods. Like with iron, the largest amounts of copper detected were found at Um Greifat, while Um Gheig again has higher concentrations detected than Wadi Igla. Concentrations of copper detected were much larger than the uncontaminated samples with the exception of the organic components at Wadi Igla. Shells and tissues detected accumulation of copper in the gastropods.

The spatial data suggests that the highest accumulations of metals are coming from the northernmost locality of Um Gheig. Um Gheig was the site that has been observed in previous studies by El-Wekeil, which is 6 km west from a lead mine. The nature of the lead mine is strong accumulations of lead and zinc that have gone up to the surface, which is flowing from the mines downstream by rivers to the coastline where the gastropods live. The other notable spatial data suggests that the highest concentrations of iron and copper are occurring at site 2 of Um Greifat. As mentioned above, Um Greifat is only 9 km inland from an iron mine, which suggests that this is the source for iron and copper metal pollution. Iron oxides eroding from the red ochre could potentially flow into the rivers nearby the iron mine, and flow downstream to the coastline where the gastropods live, like what we see in site 1 Um Gheig. Since site 3 Wadi Igla had the lowest concentrations of metal accumulation, it is not likely contamination is coming from there, and that ocean current is not transporting heavy metals along the coastline where the gastropods live since ocean current usually flows north. However, the ocean current flows south during the summer months, which could potentially carry the high accumulation of heavy metals at northernmost Um Gheig to the southern locations along the coastline.

Conclusion:

The gastropod samples collected at all three localities have accumulated high concentrations of the heavy metals manganese, iron, copper, zinc and lead. Generally, the highest concentration of heavy metal accumulation was in the northernmost site of gastropod collection in Um Gheig. Iron and copper concentrations were highest in Um Greifat, but still showed higher concentrations detected in Um Gheig than in Wadi Igla. The gastropods collected along the coast of the Red Sea are being exposed to heavy metals in their environment and are accumulating these metals in their shells and soft tissues. Factors that could have been added for this study, or for further research, would be to examine the difference in heavy metal accumulation of each species with an in depth analysis. The fact that our data showed the raw fact that both species are accumulating concentrations of heavy metals gave the information that was needed.

The area with the highest contamination source has potential factors that are bringing toxic heavy metals along the coastline where the gastropods live. The lead mine that is 6 km inland of Um Gheig is a potential source of the heavy metals, which coincidentally all of our average sample collections had the highest concentrations of manganese, zinc, and lead at this location. The fact that there is presence of streams downstream from the lead mine to the coastline means that metals could travel downstream by rivers to the coastline.

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