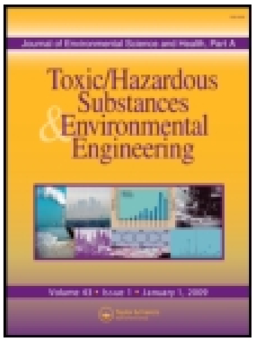


Journal of Environmental Science and Health, Part A

Toxic/Hazardous Substances and Environmental Engineering

ISSN: 1093-4529 (Print) 1532-4117 (Online) Journal homepage: http://www.tandfonline.com/loi/lesa20

LEVELS OF TRACE METALS AND EFFECT OF BODY SIZE ON METAL CONTENT OF THE LANDSNAIL LEVANTINA HIEROSYLIMA FROM THE WEST BANK–PALESTINE

Khalid M. Swaileh , Nawal Rabay'a , Radi Salim , Ademar Ezzughayyar & Alfred Abed Rabbo

J. ENVIRON. SCI. HEALTH, A36(7), 1373–1388 (2001)

LEVELS OF TRACE METALS AND EFFECT OF BODY SIZE ON METAL CONTENT OF THE LANDSNAIL *LEVANTINA HIEROSYLIMA* FROM THE WEST BANK–PALESTINE

Khalid M. Swaileh,[1,*] Nawal Rabay'a,[2] Radi Salim,[2] Ademar Ezzughayyar,[1] and Alfred Abed Rabbo[3]

[1]Dept. of Biology and Biochemistry, Birzeit University, P.O. Box 14, Birzeit, West Bank, Palestine
[2]Dept. of Chemistry, An-Najah National University, P.O. Box 7, Nablus, West Bank, Palestine
[3]Water and Soil Environmental Unit, Dept. of Chemistry, Bethlehem University, P.O. Box 9, Bethlehem, West Bank, Palestine

ABSTRACT

Levels of four trace metals (Cu, Zn, Cd and Pb) were determined in the landsnail *Levantina hierosylima* from four locations in the West Bank. Average concentration of the metals was 126.9, 42, 20.2 and 19.4 ppm for Cu, Zn, Pb and Cd, respectively. Significant differences in metal concentrations were observed between snails from the four sampling sites (Jerusalem, Abu-Dies, Qarawa, and Taibeh). Differences are most probably due to atmospheric fallout of metals from traffic roads and industrial facilities. Effect of snail size (weight and shell width) on metal content was investigated for the four metals. Plotting metal content against soft tissue weight resulted in significant relationships. Small snails were found to be richer in Zn, Cd and Pb than larger ones. Regression coefficients for the relationships were 0.75, 0.76 and 0.81 for Pb, Cd and Zn, respectively. Copper content was directly related to body weight (regression

* Corresponding author. E-mail: kswaileh@birzeit.edu

coefficient = 0.96) indicating that Cu concentration is independent of body weight. Plotting metal content against shell width indicated similar results but with less strong correlation coefficients. *L. hierosylima* is a promising bioindicator for metal pollution and further laboratory investigations are needed in order to know more about the uptake and release of metals by this organism.

Key Words: Bioindicator; Landsnails; *Levantina hierosylima*; Metals; Body size.

INTRODUCTION

In the West Bank, environmental quality has been neglected over the past 30 years; little has been invested in environmental studies, protection or even awareness. Pollution and shortage of water are the most serious causes of the unacceptable environmental situation. Meanwhile, about 90% of the wastewater in Palestine is discharged without treatment into the environment causing pollution to the already scarce water resource (1). This has lead to a continuous deterioration of the natural habitats and resources (2, 3). The extent to which the environment has deteriorated is yet to be estimated. Therefore, environmental assessment studies and surveying are urgent to help environmental protection and planning. For this purpose, there is a need to search for and develop suitable biomonitors in this region.

Snails and slugs are an important component of the herbivorous and detritivorous fauna in many ecosystems (4). Moreover, snails and slugs, with high population densities, constitute important prey for mammals, birds and other invertebrate predators (5). The use of molluscs as quantitative biomonitors for trace metal pollution, especially in aquatic ecosystems, has been known for decades (6, 7, 8, 9). The suitability of terrestrial gastropods for biomonitoring purposes was investigated. It was found that only few data are available for terrestrial molluscs compared to a great amount of literature for aquatic ones (10, 11). Generally, most snail species can be considered as good bioaccumulators for many metals like Cu, Cd, Pb and Zn (12, 13, 14, 15, 16, 17). As a result, snails can be important as agents of food chain transport of some metals, especially Pb, Cu and Cd (18, 19). Recent studies have found that high metal concentrations can affect the fitness of landsnails, like *Helix aspersa*. This could lead to disappearance of snails from polluted areas (20). Metal content of an organism depends on many factors like age (size), season and sex (9, 21, 22, 23). This makes comparing results of different studies difficult, especially when size of organisms in each study is different. To overcome this problem, attempts have been made to calculate the relationship between metal content and body size (8, 9, 21, 23). It was found that plotting metal content against body size usually produces a curved relationship (metal content = a (size)^b). Upon logarithmic transformation, a straight-line relationship (log "metal content" = log a + b log "size") can be obtained. If the relationship remains constant for each metal and species, then comparisons between different samples of the same species could be based only on the intercept (log a) by referring to a standard weight of 1, since $\log 1 = 0$ (21, 23, 24).

In the West Bank, two families (Helicidae and Enidae) dominate the landsnails. These two families account for about 50% of the species, while the remaining 50% is distributed among 20 other families (25). The helicid, *Levantina*, is represented in the West Bank by two parapatric species, *L. caesariana* and *L. hierosylima* (26). The former is distributed in the northern parts of the West Bank while, the later is localized in Jerusalem, Ramallah and adjacent areas (25). *Levantina* is of reasonable size, and gives adequate tissue for analysis. Therefore, it could be a candidate bioindicator for pollutants in the West Bank. This study is intended as a first step in this direction by focusing on investigating heavy metals in *L. hierosylima* as a potential bioindicator for future environmental surveying. Therefore, concentrations of four heavy metals (Cu, Cd, Pb and Zn) have been determined in *L. hierosylima* from different locations in Jerusalem-Ramallah area. In addition, the effect of snail's body size on metal content has been investigated.

MATERIALS AND METHODS

Sampling and Preparation of Samples

Specimens of *L. hierosylima* were collected by hand from four suburban sites in the West Bank (East Jerusalem, Abu-Dies, Qarawa and Taibeh) in April 1995. Specimens were cleaned and kept in the laboratory in a glass aquarium for two days to avoid their gut contents. Thereafter, specimens were put in plastic bags and killed by freezing. Later, shell width of each specimen was measured to the nearest 0.1 mm using a caliper. Shells were crushed and the flesh put in clean glass vials, oven-dried at 60°C to constant weight and ground to powder.

Analytical Procedure

Sub-samples of about 0.03 g were digested in a mixture of 1:1 nitric: perchloric super pure acids (Merck). The mixture volume (ml) was 10 times the sample's weight (g). Digestion continued for about 6 hours during which the temperature was raised gradually up to 200°C. At the end, volumes were brought to 5 ml in volumetric flasks and analyzed for metals using a graphite furnace atomic absorption spectrophotometer (Pye Unicam). Reference material used for quality assurance was Mussel Tissue CRM 278, Commission of the European Communities. All accepted recoveries were within two standard errors of the certified values.

Calculations and Statistics

Metal content (μg metal/individual) was calculated by multiplying metal concentration (μg .g^{-1}) by individual's weight (g). Statistical treatment of the data was done using SYSTAT-software (27).

RESULTS

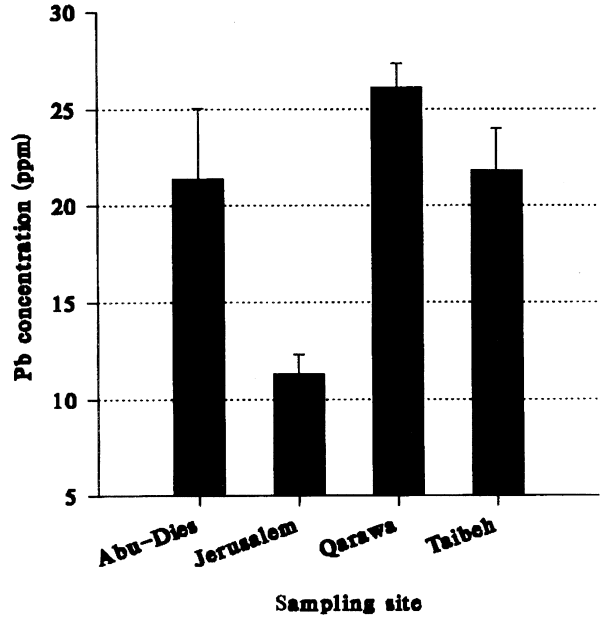
Geographical Differences in Metal Concentration

Differences between adult *L. hierosylima* specimens (shell width 30–40 mm) from the four sampling sites were investigated using analysis of variance (ANOVA), which indicated significant differences ($p < 0.05$) between the sampling sites (Figure 1). The Tukey Test (the pairwise comparison test) showed that snails from Taibeh had significantly less Cu (mean 91.7 ppm) than those from Qarawa (mean 146.1 ppm). Other pairwise comparisons between sites for Cu did not show any significant difference. Specimens from Abu-Dies and Taibeh had significantly higher mean Cd levels (28 and 20 ppm, respectively) than those collected at Jerusalem (13.3 ppm). In addition, specimens from Abu-Dies (28 ppm) had significantly higher mean Cd concentration than those from Qarawa (16.1 ppm). With regard to Pb, specimens from all stations were found to have significantly higher mean concentrations (Qarawa = 26.2, Taibeh = 21.8, and Abu-Dies = 221.3 ppm) than those from Jerusalem (11.3 ppm). For Zn, the only significant difference was between specimens from Qarawa (mean 30 ppm) and Taibeh (mean 57.1 ppm).

Effect of Size on Metal Content

Effect of body size (dry tissue weight and shell width) on metal content (μg) was investigated for the four metals. Specimens of all sizes available from the Jerusalem site were used for this purpose since the highest number of snails was found at this site. The relationships between body weight and metal content (Figure 2) were highly significant ($p < 0.0001$). Correlation coefficients (r-values) were 0.64 for Pb, 0.73 for Cd and 0.77 for both Cu and Zn. The slopes (regression coefficients) ranged between 0.96 for Cu and 0.75 for Pb.

(1a)



(1b)

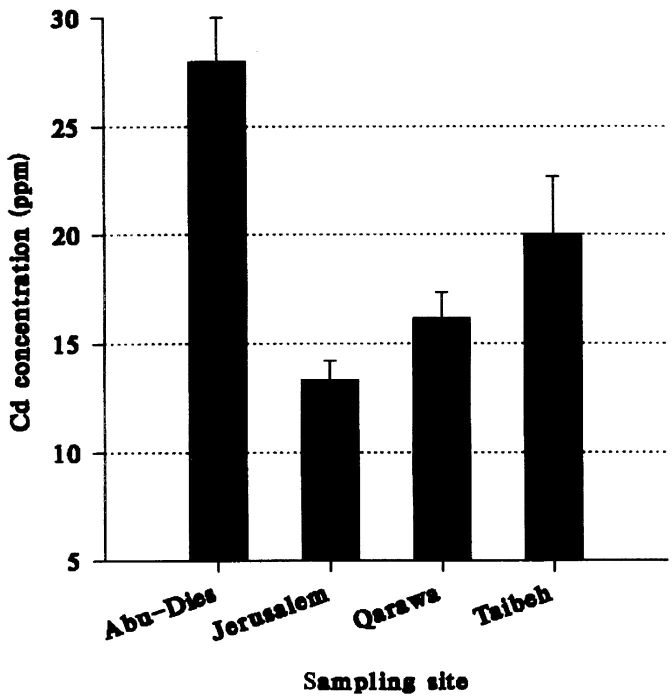
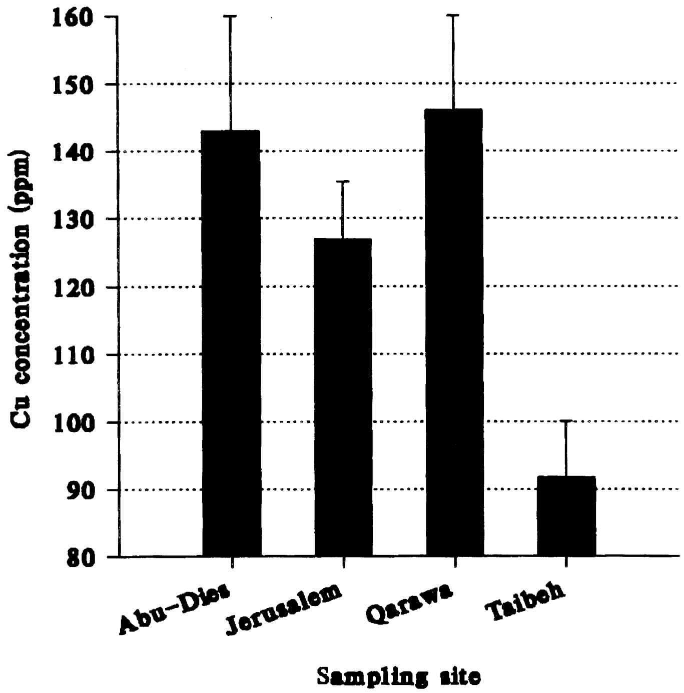


Figure 1. Mean (± SE) concentrations of four trace metals in *Levantina hierosylima* from four sites in the West Bank. Means are statistically different at $p < 0.05$. N = 10 (Abu-Dies), 46 (Jerusalem), 24 (Qarawa) and 19 (Taibeh).

(*continued*)

(1c)



(1d)

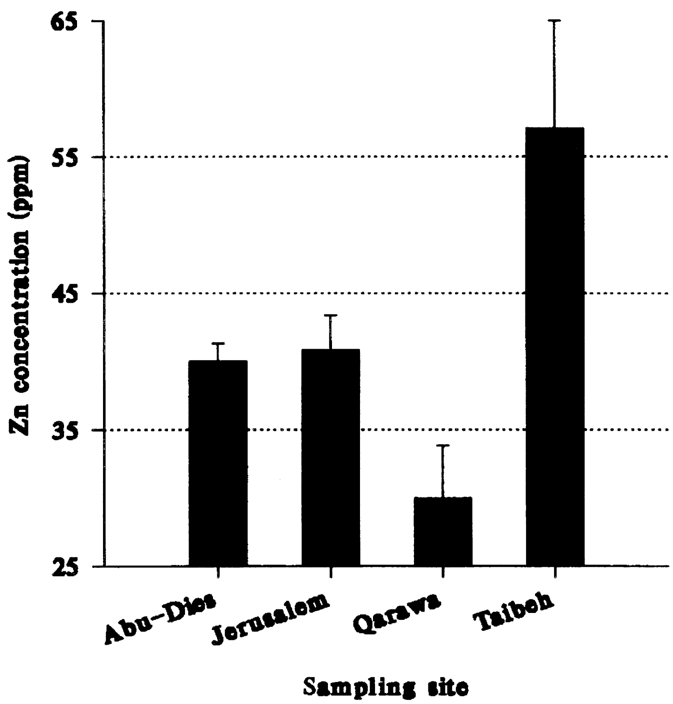
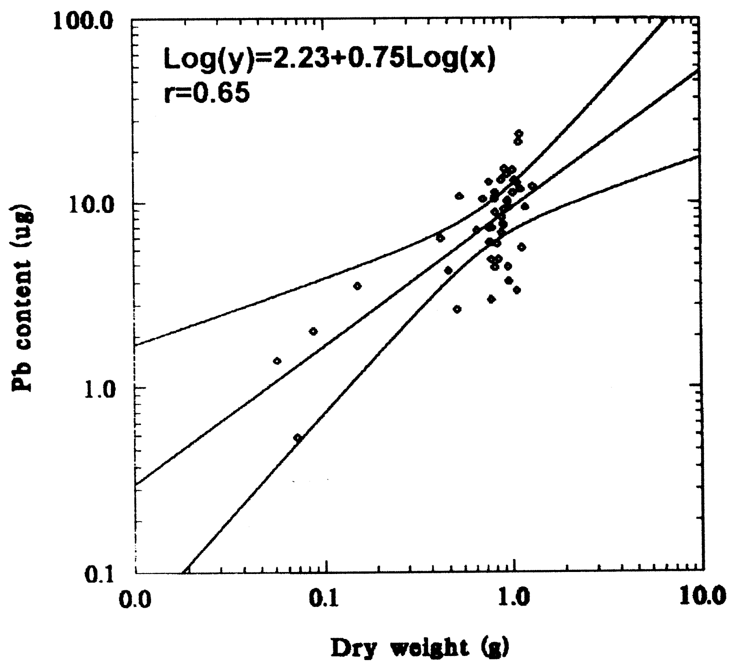


Figure 1. Continued

(2a)



(2b)

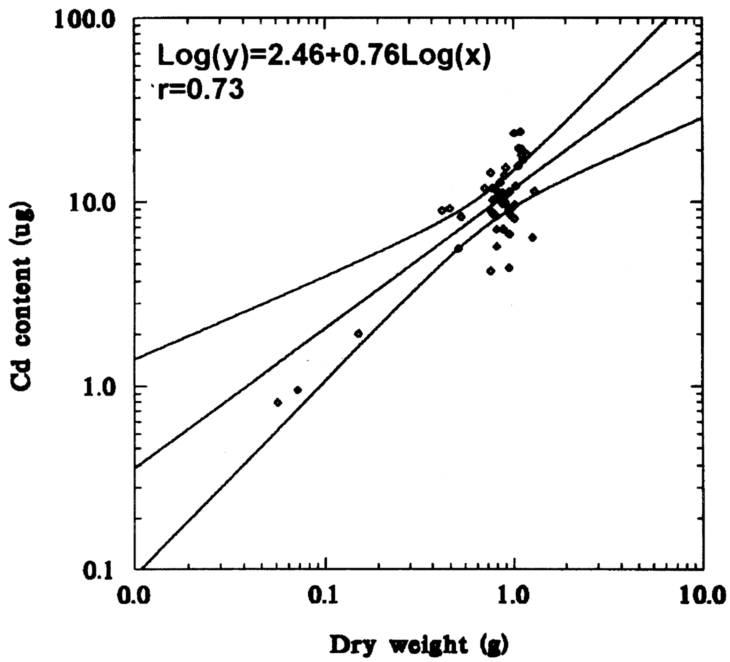


Figure 2. Relationships (± 95% confidence limits) between contents (μg) of four metals and dry tissue weight (g) of *Levantina hierosylima* from the Jerusalem site in the West Bank. All relationships are statistically significant ($p < 0.0001$), $n = 53$.

(*continued*)

(2c)

(2d)

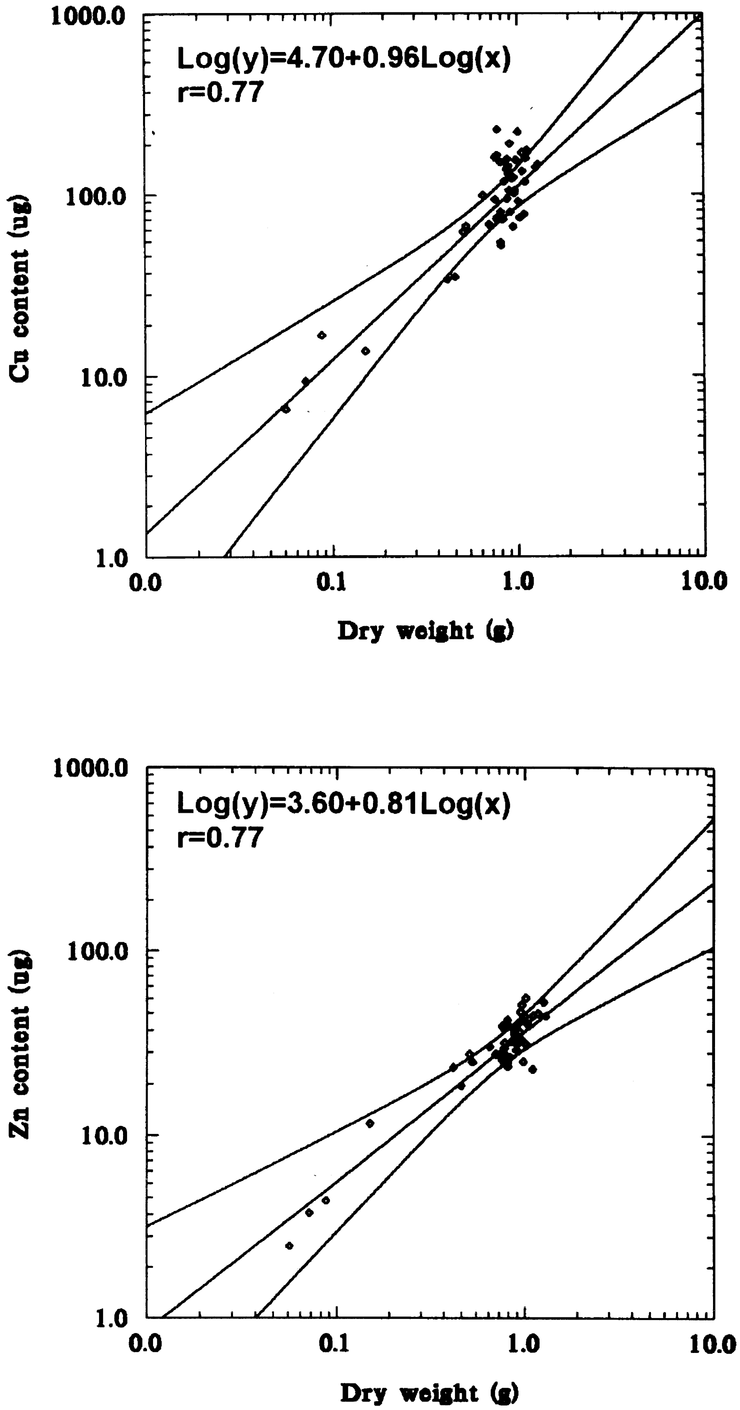


Figure 2. Continued

MARCEL DEKKER, INC.
270 Madison Avenue, New York, New York 10016

Plotting metal content against shell width on double logarithmic scales (Figure 3) resulted in similar significant linear relationships ($p < 0.0001$). Slopes ranged between 3.53 for Cu and 2.76 for Cd. Shell width was plotted against dry body weight of *L. hierosylima* on double logarithmic scales (Figure 4). The linear relationship obtained was significant at $p < 0.0001$. The two size parameters were found to correlate strongly ($r = 0.93$). Some significant correlations ($p < 0.05$) between metal contents were observed. The correlation coefficients were 0.44 for Cu-Cd, 0.42 for Pb-Cd, 0.43 for Zn-Cd and 0.3 for Pb-Zn.

DISCUSSION

Snails collected during this study were from suburban sites. No major source of pollution was observed in the vicinity of any of the sites. Differences in metal concentration between snails from different sites could be due to atmospheric fallout from traffic roads or industrial areas. In addition, soil parent rocks may have different concentrations in metals. As seen in Figure 1,

(3a)

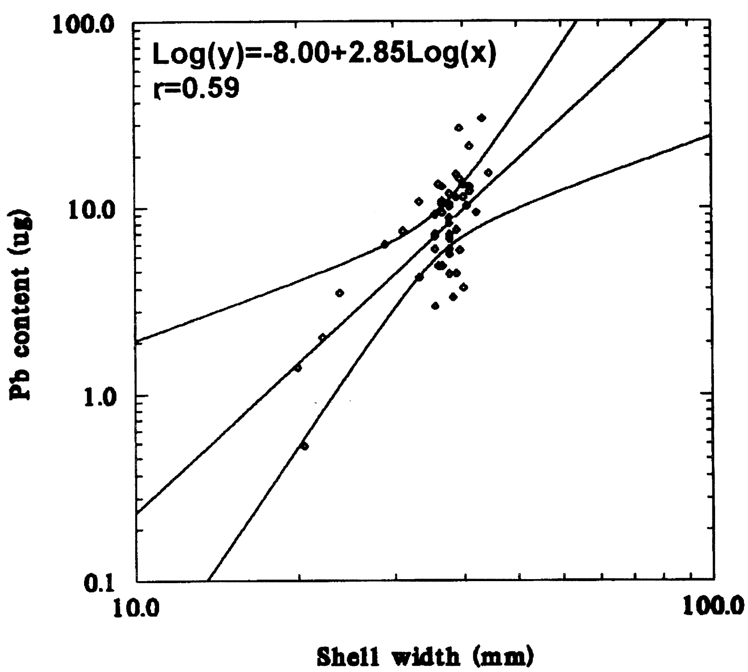
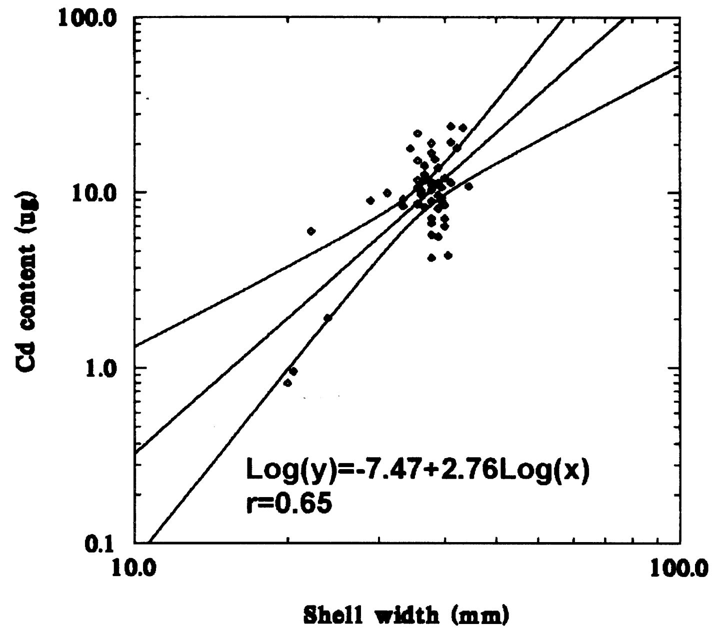


Figure 3. Relationships (± 95% confidence limits) between contents (μg) of four metals and shell width (mm) of *Levantina hierosylima* from the Jerusalem site in the West Bank. All relationships are statistically significant (p < 0.0001), n = 53.

(*continued*)

(3b)



(3c)

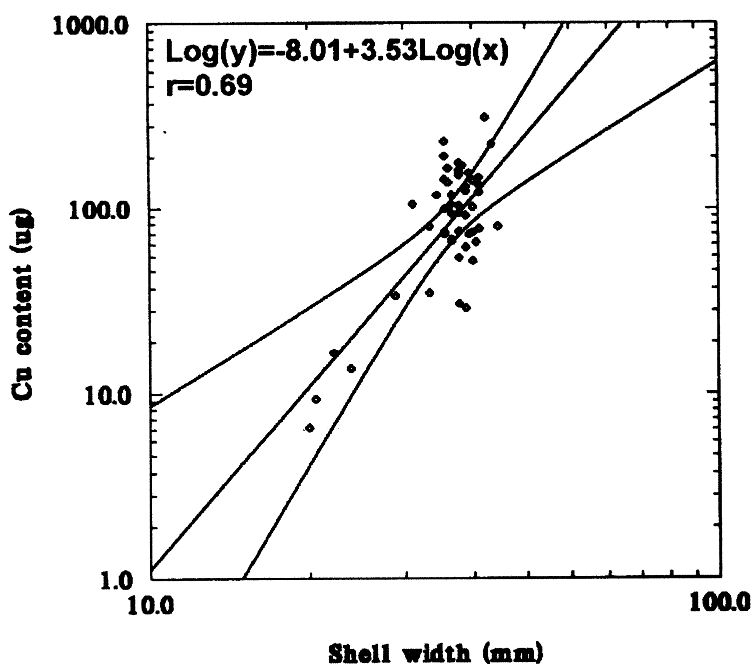


Figure 3. Continued

(3d)

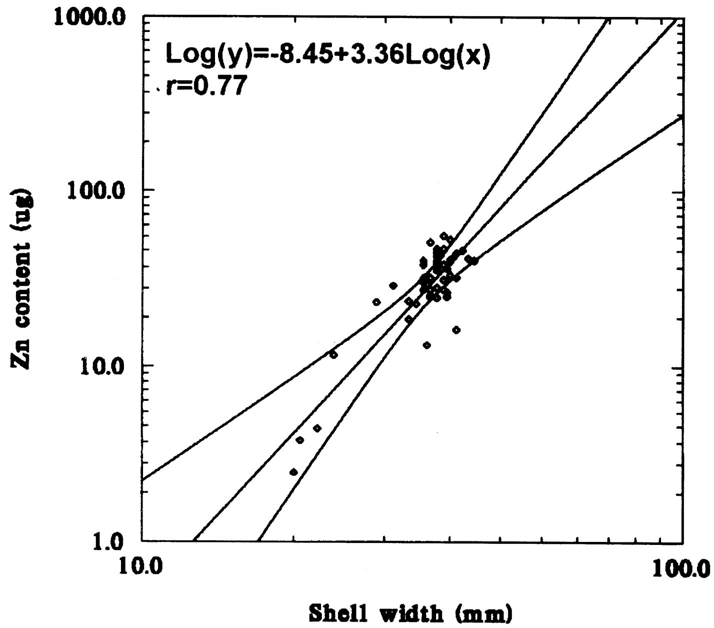


Figure 3. Continued

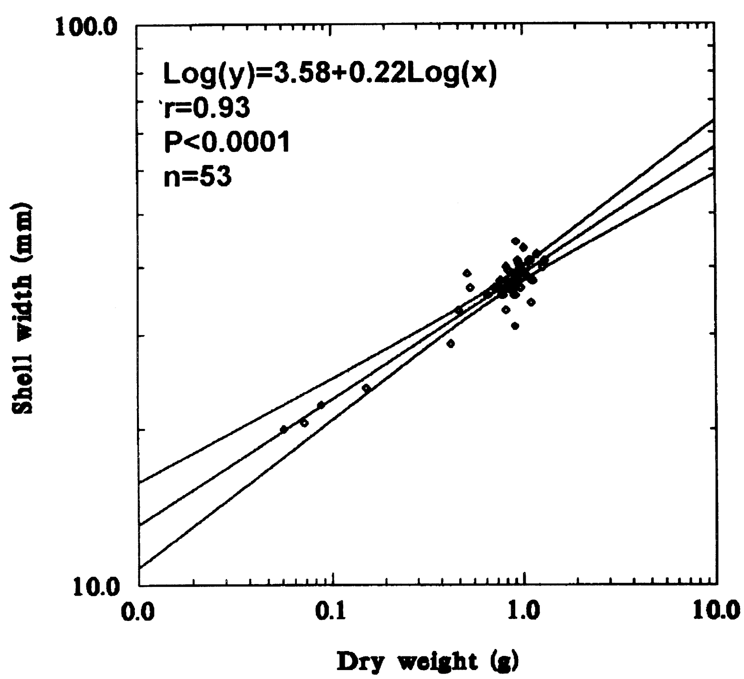


Figure 4. Relationship (± 95% confidence limits) between shell width (mm) and dry tissue weight (g) of *Levantina hierosylima* from the Jerusalem site in the West Bank. The relationship is statistically significant ($p < 0.0001$), $n = 53$.

specimens collected at Jerusalem had the least concentration of the non-essential metals, Cd and Pb; otherwise, clear trends were not observed. For most metals, sites with the highest concentrations were found to twice that of those with the lowest ones. In general, snails were found to be richest in Cu (average for all stations 126.9 ppm) followed by Zn (42 ppm), Pb (20.2 ppm) and Cd (19.4 ppm). Cu and Zn are two essential metals that could be regulated, at least partially, by molluscs (24, 28, 29, 30). However, this is not always applicable since organisms with haemocyanin, such as gastropods and isopods, have been found to accumulate Cu over a broad range of environmental concentrations (31, 32). In the present study, Cu concentration was almost three times as much as Zn concentration. Thus, it is possible that *L. hierosylima* accumulates Cu to be used in haemocyanin synthesis. The average concentrations of the non-essential metals, Cd and Pb, were close to each other. The concentration of these two metals in molluscs usually reflects environmental exposure (30).

Plotting metal content against body weight or shell width on double logarithmic scales resulted in significant linear relationships. Boyden (9) calculated the regression slopes for 131 plots of metal content against body weight of mollusc. He found that the slopes of most lines fall in two main categories: those around 0.77 and those close to 1. This indicates that metal concentrations commonly decrease or remain constant with increasing weight of molluscs. Similar results were observed for *Mytilus edulis* (33) and *Arctica islandica* (23). In the present study, plots of Cd, Pb and Zn contents against dry body weight of *L. hierosylima* (Figure 2) gave slopes ranging between 0.75 and 0.81 (average slope 0.773). This average value is in full agreement with the findings of Boyden (9). This means that the concentrations of these three metals (Cd, Pb and Zn) decrease with size of *L. hierosylima* and that larger specimens contain less metals than would be predicted if content was directly related to size. Similar results for Pb and Zn in *Patella vulgata* and *P. intermedia* were observed (8). Also, similar results were observed for Zn in *Arctica islandica* (23) and *Mytilus edulis* (33). In a roadside population of the snail *Cepaea hortensis,* it was found that smaller snails were richer in Pb, Cd and Zn than larger ones (34). It was suggested that, this pattern could be due to variations in metabolic activity of the snail with size, which would affect metal uptake and elimination.

Regression coefficients of metal contents related to body weight by a power of 0.77 indicate a connection with metabolism, since many metabolic processes display a similar relation to body weight (8). This regression coefficient (0.77) is very close to the 0.75 coefficient describing the relationship of respiration of poikilotherms to body weight (35). This value is generally applicable to many metabolic functions when related to weight.

The effect of snail size on Cu content was different from that for the other three metals. The regression slope for Cu content against body weight was 0.96, very close to 1. This indicates that Cu content is directly related to size and hence, Cu concentration is independent of size of *L. hierosylima*. In such a case, a function of body weight, such as the binding of a specific compound within the tissue, may play some role in determining the total body metal burden (8). A slope of 1 for the relationship between log metal content and log body weight implies a total control of this metal by metabolism (36). The content of some essential metals, like Cu & Zn, could be growth-dependent rather than age-dependent (24, 37). In the present study, Cu was directly related to tissue weight and thus it seems to be growth-dependent.

In molluscs, metals are distributed through a number of compartments. Two important ones are the circulating and storage compartments (38, 39). The relative importance of these compartments could account for the slope of the metal content/body size regression. Molluscs increase the storage compartment by synthesizing metal-binding proteins (11, 40) or by forming metal granules (39, 41, 42).

Regressions of metal content against shell width (Figure 3) indicate similar results to those obtained by relating metal content to body weight (Figure 2). When shell width was plotted against body weight of *L. hierosylima* on logarithmic scales, a strong linear relationship was obtained (Figure 4). The correlation coefficient for this relationship was 0.93. This means that these two parameters could be equally suitable as indicators of size. However, correlation coefficients for metal contents and body weight are stronger, for all metals except Zn, than those for metal contents and shell width. This could be due to the fact that metabolic processes and growth of the animal affect metals directly. The shell grows in response to tissue growth and thus, the relationship between metal content and shell size is indirect.

Laboratory experiments on the accumulation and release patterns of heavy metal in *L. hierosylima* are recommended before this species is used in future monitoring programs.

ACKNOWLEDGMENTS

The authors wish to thank Miss Reem Zeitoun, Bethlehem University for her assistance in analysing the samples by AAS. This research was financially supported by a grant from Birzeit University to Dr. K. M. Swaileh and Dr. A. Ezzughayyar.

REFERENCES

1. Ministry of Environmental Affairs (MEnA). *Palestinian Environmental Strategy* (*PES*). MEnA: Al-Bireh, Palestine, 1999, 94 pp.

2. Issac, J. Environmental Protection and Sustainable Development in Palestine. In: *Our Shared Environment*; Twite, R., Issac, J., Eds.; IPCRI: Jerusalem, London, Oakland, 1994; 7–21.
3. Shtayyeh, M.S.; Hamad, A.K. *Protecting the Palestinian Environment*. AL- Nasser Publ.: Nablus, Palestine, 1995; 357pp.
4. Russel-Hunter, W.D. Overview: Planetary Distribution and Ecological Constrains upon the Mollusca. In: *The Mollusca*; Russel-Hunter, D.W., Ed. Academic Press: London, 1983; 1–27.
5. Graveland, J.; van der Wal, R.; van Balen, J.H.; van Noordwijik, A.J. Poor Reproduction in Forest Passerines from Decline of Snail Abundance on Acidified Soils. Nature **1994**, *368*, 446–448.
6. Phillips, D.J.H. The Use of Biological Indicator Organisms to Monitor Trace Metal Pollution in Marine and Estuarine Environments.- a review. Environ. Pollut. **1977**, *13*, 281–317.
7. Phillips, D.J.H. *Quantitative Aquatic Biological Indicators, their Use to Monitor Trace metal and Organochlorine Pollution*. Applied Science Publisher: London, 1980; 487 pp.
8. Boyden, C.R. Trace Element Content and Body Size in Molluscs. Nature **1974**, *251*, 311–314.
9. Boyden, C.R. Effect of Size upon Metal Content of Shellfish. J. Mar. Biol. Ass. UK. **1977**, *57*, 675–714.
10. Berger, B.; Dallinger, R. Accumulation of Copper and Cadmium by Terrestrial Snail *Arianta Arbustorum* L.: Kinetics and Budgets. Oecologia **1989**, *79*, 60–65.
11. Berger, B.; Dallinger, R. Terrestrial Snails as Quantitative Indicators of Environmental Pollution. Environ. Monitor. Assess. **1993**, *25*, 65–84.
12. Beeby, A.; Richmond, L. Adaptation by an Urban Population of the Snail *Helix aspersa* to Diet Contaminated with Lead. Environ. Pollut. **1987**, *46*, 73–82.
13. Knutti, R.; Bucher, P.; Stengel, M.; Stoltz, M.; Tremp, J.; Ulrich, M.; Schlaffer, C. Cadmium in the Invertebrate Fauna of an Unpolluted Forest in Switzerland. Environ. Toxin. Ser., **1988**, *2*, 171–191.
14. Hopkin, S.P. *Ecophysiology of Metals in Terrestrial Invertebrates*. Elsevier Applied Sciences: London, 1989; 1–366.
15. Dallinger, R. Strategies of Metal Detoxification in Terrestrial Invertebrates. In: *Ecotoxicology of Metals in Invertebrates*, Dallinger, R., Rainbow P.S., Eds.; Lewis Publ.: Boca Raton, 1993; 245–289.
16. Rabitsch, W. B. Metal Accumulation in Terrestrial Pulmonates at a Lead/Zinc Smelter Site in Arnoldstein, Austalia. Bull. Environ. Contam. Toxicol. **1996**, *56*, 734–741.
17. Gomot, A.; Pihan, F. Comparison of the Bioaccumulation Capacities of Copper and Zinc in Two Snail Subspecies (*Helix*). Ecotoxicol. Environ. Saf. **1997**, *38*, 85–94.
18. Beeby, A.J. The Role of *Helix aspersa* as a Major Herbivore in the Transfer of Lead through a Polluted Ecosystem. J. Appl. Ecol. **1985**, *22*, 267–275.
19. Laskowski, R.; Hopkin, S. Accumulation of Zn, Cu, Pb, and Zn in the Garden Snail (*Helix aspersa*): Implications for Predators. Environ. Pollut., **1996**, *91*(3), 289–297.

20. Laskowski, R. & Hopkin, S. Effect of Zn, Cu, Pb, and Cd on Fitness in Snail (*Helix aspersa*). Ecotoxicol. Environ. Saf. **1996**, *34*, 59–69.
21. Fischer, H. Shell Weight as an Independent Variable in Relation to Cadmium Content in Molluscs. Mar. Ecol. Prog. Ser. **1983**, *12*, 59–75.
22. Swaileh, K.M.; Mesmar, M.N.; Ismail, N. Heavy Metal Concentration in Common Freshwater Snails from Azraq Oasis-Jordan. *Hydrobiol*. **1994**, *286*, 167–173.
23. Swaileh, K.M.; Adelung, D. Levels of Trace Metals and Effect of Body Size on Metal Content and Concentration in *Arctica islandica* L. (Mollusca: Bivalvia) from Kiel Bay, Western Baltic. Mar. Pollut. Bull. **1994**, *28* (8), 500–505.
24. Swaileh, K.M. Effect of Body Size and Season on the Concentration of Cu, Cd, Pb and Zn in *Arctica islandica* (Mollusca:Bivalvia) and *Diastylis rathkei* (Crustacea: Cumacea) from Kiel Bay, Western Baltic Sea. Ph.D Thesis, Institute of Marine Sciences, Kiel University: Kiel, Germany, 1995, 122 pp.
25. Heller, J. The Biogeography of the Land Snails of Israel. In*: The Zoogeography of Israel; the Distribution and Abundance at a Zoogeographical Crossroad*; Y. Yom-Tov, Y., Tchernov, E., Eds.; Dordrecht, 1988; 325–353.
26. Mienis, H.K. A checklist of the Land Molluscs of Israel and the Administered Areas. Levantina **1982**, *39*, 457–465.
27. Wilkinson, L. *SYSTAT for Windows*, Version, 5.02; SYSTAT Inc.: Evanston, IL; USA, 1992.
28. Phillips, D.J.H.; Yim, W.W.S. A comparative Evaluation of Oysters, Mussels and Sediments as Indicators of Trace Metals in Hong Kong Waters. Mar. Ecol. Prog. Ser. **1981**, *6*, 251–258.
29. Sandler, H. Zinc and Copper Concentrations in Benthic Invertebrates Considered in Relation to Concentrations in Sedimemts and Water in Bothnian Sea (Northern Baltic). Finn. Mar. Res. **1984**, *250*, 19–32.
30. Amiard, J.C.; Amiard-Triquet, C.; Berthet, B.; Metayer, C. Comparative Study of the Patterns of Bioaccumulation of Essential (Cu, Zn) and Non-essential (Cd, Pb) Trace Metals in Various Estuarine and Coastal Organisms. J. Exp. Mar. Biol. Ecol. **1987**, *106*, 73–89.
31. Hughes, M.K.; Lepp, N.W.; Phipps, D.A. Aerial Heavy Metal Pollution and Terrestrial Ecosystems. In: *Advances in Ecological Research,* vol 11; Mac Fadyen, A., Ed. Academic Press: London, 1980; 217–327.
32. Hopkin, S.P. Species-Specific Differences in the Net Assimilation of Zn, Cd, Pb, Cu and Fe by Terrestrial Isopod *Oniscus asellus* and *Porcellio scaber*. J. Appl. Ecol. **1990**, *27*, 460–474.
33. Cossa, D.; Bourget, E.; Pouliot, D.; Piuze, J.; Chanut, J.D. Geographical and Seasonal Variations in the Relationship between Trace Metal Content and Body Weight in *Mytilus edulis*. Mar. Biol. **1980**, *58*, 7–14.
34. Williamson, P.D. Variables Affecting Body Burdens of Lead, Zinc and Cadmium in a Roadside Population of the Snail *Cepaea hortensis* Müller. Oecologia (Berl.), **1980**, *44*, 213–220.
35. Hemmingsen, A.M. Energy Metabolism as Related to Body Size and Respiratory Surfaces and its Evolution. Reports of the Steno Memorial Hospital and the Nordisk in Sulinlaboratorium **1960**, *9*, 1–110.
36. Fagerstroem, T. Body Weight, Metabolic Rate and Trace Substance Turnover in Animals. Oecologia (Berl.) **1977**, *29*, 99–104.

37. Lobel, P.B.; Wright, D.A. Relationship between Body Zinc Concentration and Allometric Growth Measurements in the Mussel *Mytilus edulis*. Mar. Biol. **1982**, *66*, 145–150.
38. Coombs, T.L. The Distribution of Zinc in the Oyster *Oystrea edulis* and its Relation to Enzymatic Activity and to other Metals. Mar. Biol. **1972**, *12*, 170–178.
39. Coombs, T.L.; George, S.G. Mechanism of Immobilization and Detoxification of Metals in Marine Organisms. In: *Physiology and Behaviour of Marine Organisms*; McLusky, D.S., Berry, A.J., Eds; Pergamon Press: Oxford, 1978; 179–187.
40. Noel-Lambot, F. Distribution of Cd, Zn and Cu in the Mussel *Mytilus edulis*, Existence of Cd-Binding Proteins Similar to Metallothionines. Experientia **1976**, *32*, 324–325.
41. Simkiss, K.; Taylor, M.G. Convergences of Cellular Systems of Metal Detoxification. Mar. Environ. Res. **1989**, *28*, 211–214.
42. Nott, J.A.; Nicolaidou, A. Metals in Gastropods-Metabolism and Bio-reduction. Mar. Environ. Res. **1989**, *28*, 201–205.

Received October 19, 2000