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Research Article

Cadmium Levels in the Urine of Males and Females from Different Age-groups in an Agricultural Village and Sugar-Producing Town in the Gezira State, Central Sudan

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Abstract

Cadmium (Cd) is one of the most serious environmental poisons all over the world. Exposure to Cd results in health hazards. This study aimed to determine the levels of Cd in urine among adult males, females and children of both sexes ≤ 5 yr-old, in two Gezira State (Sudan) villages, viz. Rigwa (Um Al Goura Locality) and Wadelsayed (Eastern Gezira Locality). The selected age groups were 15 - 20, 25 - 35, 40 - 50 and 55 - 65 year old. Urine samples collected from these groups were analyzed using Atomic Absorption Spectrophotometry (AAS). A completely randomized design was adopted. Results revealed presence of Cd in urine with no exception. Cd levels in urine of females in Rigwa were 0.289, 0.113, 0.203, 0.283 and 0.199 mg/L for ≤ 5, 15 - 20, 25 - 35, 40 - 50 and 55 - 65 yr-old, respectively. The levels in males were 0.087, 0.069, 0.288, 0.274 and 0.288 mg/L, respectively, for the same age groups. Regarding Wadelsayed females, the levels were 0.014, 0.020, 0.015, 0.022 and 0.040 mg/L, respectively, following the same order as above. The means for males were 0.122, 0.129, 0.051, 0.089 and 0.099 mg/L for ≤ 5, 15 - 20, 25 - 35, 40 - 50 and 55 - 65 yr. old, respectively. The females level in Rigwa were higher than those of the males in the age groups < 5, 15 - 20 and 40 - 50 yr-old, whereas in Wadelsayed the levels in men were, in many cases, by far higher than those of the females. Also, the levels in Rigwa for both sexes were higher than those in Wadelsayed. The females < 5 in Rigwa shoed the heist concentration of Cd (0.289 vs. 0.087 mg/L), whereas those of Wadelsayed were 0.014 vs. 0.122 mg/Lm following the same order.

Keywords: *Cadmium; Urine; Wadelsayed*

Introduction

Pollution is the deliberate or accidental contamination of the environment with man's waste", or "matter in the wrong place", or "anything released into the environment, which degrades it", or "the presence of matter or energy in an unusual or unintended place" [1]. A pollutant is a substance or effect, which adversely alters the environment by changing the growth rate of species, interferes with the food chain/web, is toxic, or interferes with health [2].

Virtually all metals can produce toxicity when ingested in sufficient quantities, but there are several which are especially important, because either they are so pervasive, or produce toxicity at such low concentrations. When we talk about heavy metals (HMs), we generally mean, Pb, Hg, Fe, Cu, Mg, Cd, As, Ni, Al, Ag and Be [3]. HMs produce their toxicity by forming complexes or "ligands" with organic compounds (biological molecules), which lose their ability to function properly, and result in malfunction or death of the affected cells. The most common atoms involved in ligand formation are O, S and N. When metals bind to these atoms, they may inactivate important enzyme systems, or affect protein structure. There is a considerable cross-over in many of the toxic manifestations of the different metals, and in the agents used to treat the toxicity [4].

According to Anon [5], Cd is a chemical element with an atomic number 48. This soft, bluish-white metal is chemically similar to the two other stable metals in group 12, viz. Zn and Hg. Like Zn, it prefers oxidation state +2 in most of its compounds, and like Hg, it shows a low melting point compared to transition metals. Cd is an extremely toxic metal commonly found in industrial workplaces. Due to its low permissible exposure limit, over-exposures may occur even in situations where trace quantities of Cd are found. Cd is used extensively in electroplating. Cd is also found in some industrial paints and may represent a hazard during painting. Operations involving removal of Cd paints by scraping or blasting may pose a significant hazard. Cd is also present in the manufacturing of some types of batteries. Exposures to Cd are addressed in specific standards for the general industry, shipyard employment, construction industry, and the agricultural industry [5].

Cd acts as a catalyst in forming reactive oxygen species. It increases lipid peroxidation, in addition, it depletes antioxidants, glutathione (GSH) and protein-bound sulfhydryl groups (-SH). Cd also promotes the production of inflammatory cytokines [6].

Cd waste streams from the industries mainly end up in soils. The causes of these waste streams are, for instance, zinc production, phosphate or implication and bio industrial manure. Cd waste streams may also enter the air through household waste combustion and burning of fossil fuels. Because of regulations, only little Cd now enters the water through disposal of waste-water from households or industries. Another important source of Cd emission is the production of artificial phosphate fertilizers. Part of the Cd ends up in the soil after the fertilizer is applied on farm-land and the rest of the Cd ends up in surface waters, when waste from fertilizer productions is dumped by production companies [7]. Cd can be transported over great distances when it is absorbed by sludge. This Cd-rich sludge can pollute surface-waters, as well as soils [8]. Cd strongly adsorbs to organic matter in soils. When Cd is present in soils, it can be extremely dangerous, as the uptake through food will increase. Soils that are acidified enhance the Cd uptake by plants. This is a potential danger to the animals that are dependent upon the plants for survival. Cd can accumulate in their bodies, especially when they eat multiple plants. Cows may have large amounts of Cd in their kidneys. Earthworms and other essential soil organisms are extremely susceptive to Cd poisoning. They can die at very low concentrations and this has consequences for the soil structure. When Cd concentrations in soils are high, they can influence soil processes of microorganisms and threat the whole soil ecosystem [8].

Objectives

The objective of the present study was to determine the level of Cd in the Gezira State, central Sudan, taking a small village as a representative of those far from pollution sources and another small village near an old Sugarcane factory accused of causing pollution to the village and the surrounding villages and towns.

Materials and Methods

The study was carried out in two localities out of the eight in the Gezira State localities(Longitudes: 32 25' and 34' 18 E, Latitude: 15′ 29 and 13′ 36 N), Central Sudan. These localities are Um Al Goura and East Gezira localities. The population of the Gezira State is > four million. Each locality is divided administratively into seven administrative units (total 38 units in the state).From Um Al Goura locality, Rigwa village (population of 1,700) was selected, because it is small and isolated village and far from pollution activities. The other village was from Eastern Gezira locality, namely Wadelsayed village, near Elgunaid Sugar Factory (established 1963). It was selected (population of 2,100) as a representative of polluted area. This sugar factory is accused of being one of the major polluting sources in the state [9].

Study Design

Complete Randomized Designed (CRD) with four replications was adopted. A questionnaire was used to relate the detected concentrations of these HMs to their source [10].

Study Population (groups)

Studied population was divided into five groups in each village; each group included four individual males or females as replicates, including a group of children (≤ 5 yr)/village. The age groups were ≤ 5 yr, 15 - 20, 25 - 35, 40 - 50 and 55 - 65 yr-old. These age intervals were selected for economic reasons. The individuals were randomly selected from those who agreed to participate in the study; several individual refused to participate or their the heads of their houses did not give cooperate for unknown reasons.

Urine samples collection

Samples were collected from Um Al Goura locality (population > 227,000, three administrative units), Rigwa village, and from the Eastern Gezira locality (> 500,000; five administrative units). Urine samples (80) were collected from males, females and children population, according to with the abovementioned age groups. Samples were taken on the morning (8 - 11 am) to a void dilution of HMs in the subsequent urination. Standard urine sample sterile containers were provided for the individuals (capacity 65 ml), labeled and kept in cold box (ca. 4°C). Samples were kept in a freezer until being transport inside the cold box to the laboratory for analysis [10].

Sample Size

A total of 80 urine samples were collected from each village (40 from males and 40 from females) and kept in sterile urine containers as mentioned earlier. The collected samples were subjected to Cd analysis by taking 20 ml from each sample [10].

Instruments and Glassware

The instruments and glassware used in this study were sterile urine containers, measuring cylinders of different sizes, pipettes, test tubes, volumetric flasks and Atomic Absorption Spectrophotometers (AAS) (model AA-6800, Shimadzu, Kyoto, Japan, 2005) [10].

Reagents

The reagents required for this work were Glacial acetic acid and 0.5N hydrochloric acid, and strontium (Sr^{++}) [10].

Determination of cadmium in urine

Cd levels were determined in the collected urine using a method described by Zinterrhoger., *et al*. [11]. The details of this method are explained under the titles standards preparation and samples preparation below.

Standards preparation

Standard solutions were prepared as follows: 250 μ l was taken from stock standard solution (1000 mg/L) in a plastic volumetric flask (25 ml) and made up to the mark with 0.5 N of HCl solution, to yield the intermediate standard solution (10 mg/L). Working standard solution was left to stabilize and then a series of 20, 60, 200, 600 and 800 μ l from Cd stock solutions (1000 ppm) were taken in a series of 10 ml of plastic volumetric flask and were made up to the marks using 0.5 N HCl solution. These correspond to 2, 6, 20, 60 and 80 ppm. A concentration of 0.4% strontium (Sr^{++}) was prepared from strontium chloride (as a matrix modifier). Each standard of the element was diluted with this solution to get 0.08% strontium corresponding to 1, 3, 10, 30 and 40 ppm of Cd [10]. The same procedure was followed to prepare the urine samples.

Chemical Analysis

Chemical analysis of urine samples were conducted at Shambat Central Laboratory, Faculty of Agriculture, University of Khartoum, using AAS. The AAS was adjusted as follows:

The main power supplier was turned, the valves of acetylene gas cylinder were opened, the pressure was adjusted at 0.09 and 0.35m.p., for acetylene and air, respectively. The personal computer was opened; the analysis of cd in urine was setup on the control program. The nebulizer capillary tube was transferred to the standard one solution flask and the reading of the absorption was taken then the tube was returned to the deionized water cup and waited till the digital reading reach zero value then continued on the same way for other standard solution. Before the reading of the standard or samples solution, the absorption value of the plank solution was taken (all added reagents except sample). The absorbance values were taken for sample solutions and abstract the plank value from the sample value [10].

Data analysis

Data collected from laboratory experiments were subjected to analysis using SPSS (version 11.5, 2002) statistical package software was used to perform the statistical analysis [10].

Results

Rigwa Village

Females

The Cd concentration in the urine samples collected from the females reflected a mean of 0.289 ppm in age ≤ 5 yr. group, while that collected from age 15 - 20 yr gave a mean of 0.113 ppm. The mean of for 25 - 35 yr group was 0.203 ppm, whereas that for age 40 - 50 yr group was 0.283 ppm. In the other hand, the concentration in the urine of the oldest group (55 - 65 yr) registered 0.249 ppm (Figure 1).

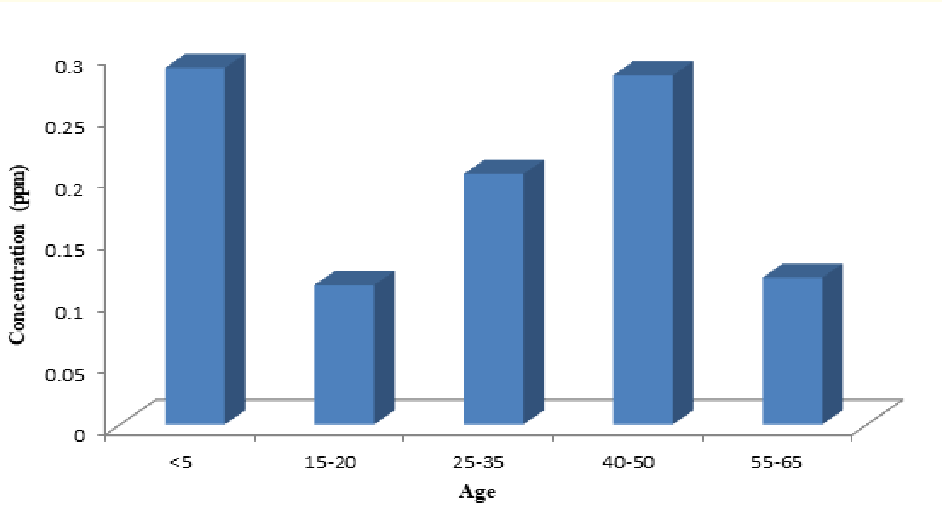

Figure 1: *Means of cadmium concentration (ppm) in females in Rigwa village.*

Males

The concentration in the samples collected from the males in Rigwa showed a mean of 0.087 ppm in age ≤ 5 yr., i.e. by far less than that of the females of the same age, while that collected from age 15 - 20 yr group gave a mean of 0.069 ppm, i.e. almost half the females concentration. The mean of for age group 25 - 35 yr was 0.288 ppm, higher than the females of the same age, whereas that collected from age group 40 - 50 yr resulted in a mean of 0.279 ppm, which was not significantly different from the females of the age. The concentration in age group 55 - 65 yr reflected a mean of 0.288 ppm, significantly higher than their female counterparts (Figure 2).

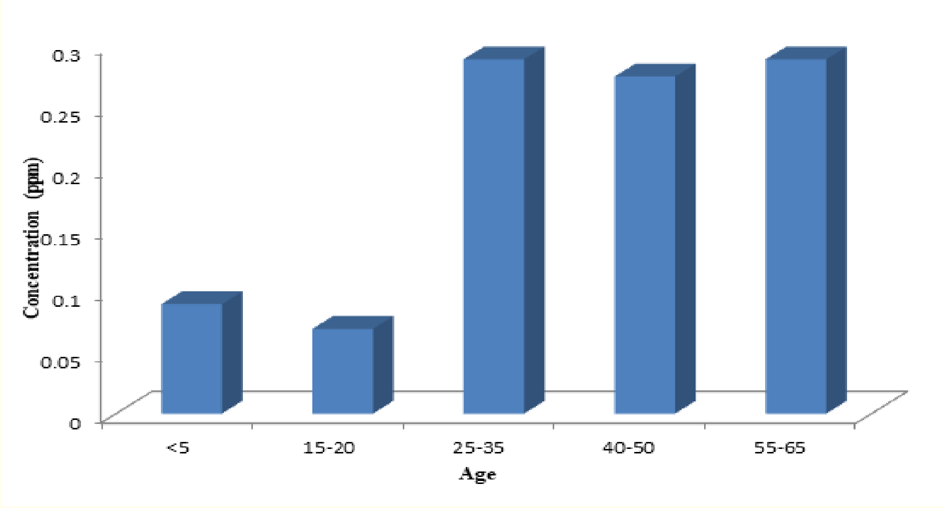

Figure 2: *Means of cadmium concentration (ppm) in males in Rigwa village.*

Wadelsayed Village

Females

The concentration in the samples collected from ≤ 5 yr age group Wadelsayed was 0.014 ppm, which is one of the lowest concentrations during this study in both villages, all age groups and sexes. The age group 15 - 20 yr showed 0.020 ppm, significantly different from the females of Rigwa. The mean for age group 25 - 35 yr, 40 - 50 yr and the age group 55 - 65 yr was 0.015 ppm, 0.022 ppm and 0.04 ppm, respectively, which were significantly different from their counterparts in Rigwa males and females. The old group showed the lowest concentration in the present study (Figure 3).

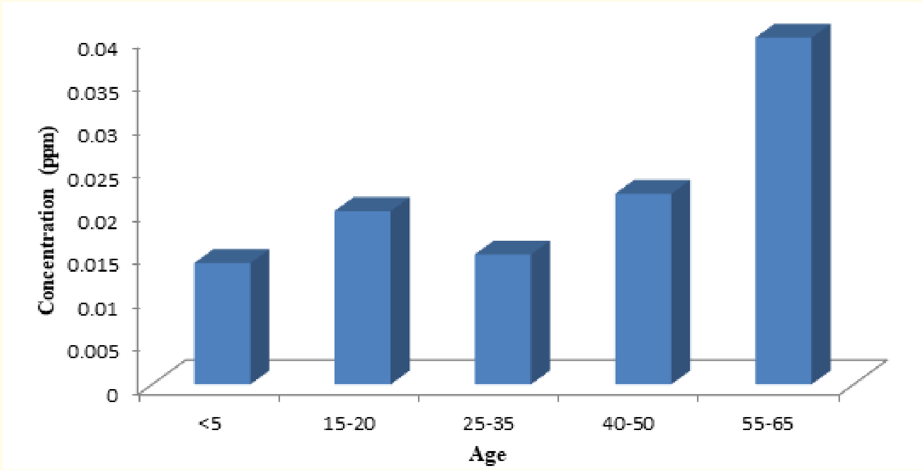

Figure 3: Means of cadmium concentration (ppm) in females in Wadelsayed.

Males

The results of Cd concentration in the urine samples for males in Wadelsayed, for the age ≤ 5 yr. group was 0.122 ppm (significantly higher than their female counterparts in the same village), while that collected from age 15 - 20 yr group was 0.129 ppm (> 6x of the females concentration in the same age group). The means for 25 - 35 yr, 40 - 50 yr and 55 - 65 yr groups, following the same order were 0.051 ppm, 0.089 ppm and 0.049 ppm, which were significantly higher than the females in the same age (Figure 4).

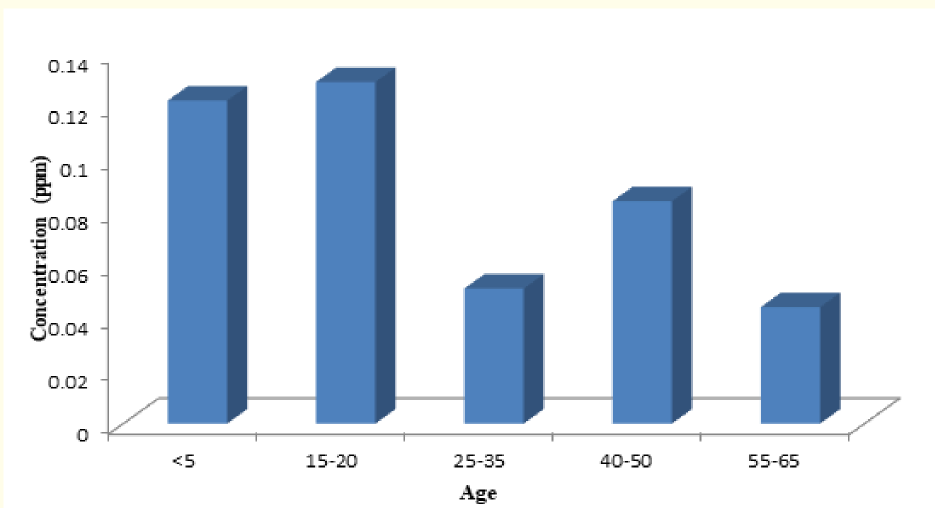

Figure 4: Means of cadmium concentration (ppm) in males in Wadelsayed.

Discussion

The analysis of urine samples of all investigated groups from Rigwa village revealed that the concentration of Cd varied between and within each population, e.g. the females reflected variations between the age-groups. The age- group of ≤ 5 yr-old (children), showed the highest level of Cd concentrations among all tested age-groups in the females population in the village. It was also the highest among all tested samples of this study in both villages. No available justification can be provided from this study. However, according to Mohamed., *et al.* [12], who studied the concentration of HMs in vegetable samples collected from different sites before and after washing, found that Cd concentration varied before and after washing. Moreover, unwashed vegetable samples collected from road-side farm showed higher concentration (0.86 mg/kg), even after washing (0.35 mg/kg). Unwashed road-side market samples also contained high level of Cd, especially tomato samples (0.32 mg/kg), i.e. above the recommended level (0.2 mg/kg) of the Codex Alimentations Commission (2001). The higher level of Cd in Rigwa village could be related to high traffic density (tractors, pickups and other means of transportation) between and within farms and villagers consume large amounts of vegetables (Figure 5).

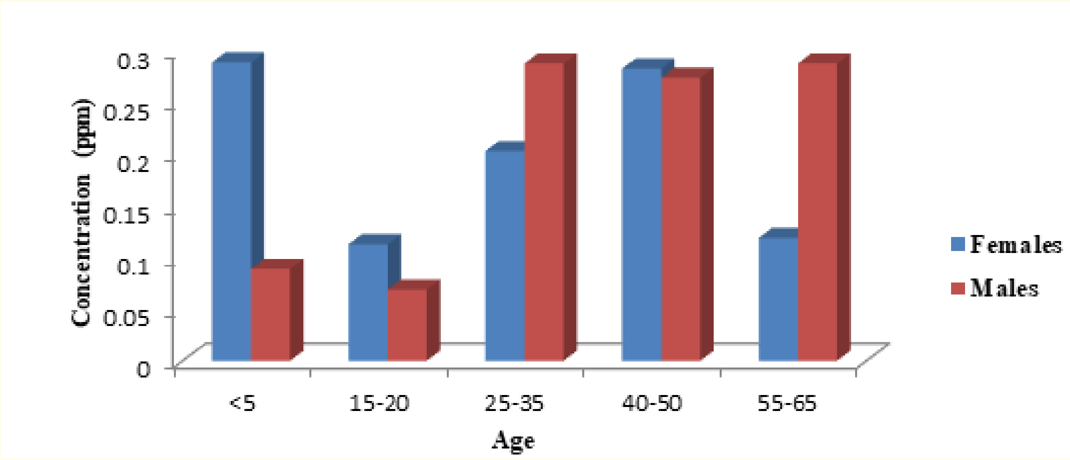

Figure 5: *Means of cadmium concentration (ppm) in males and females in Rigwa village.*

With regard to the males of Rigwa village, there were several differences between the age-groups and also between sexes. The highest Cd concentration was shown by the age-group 25 - 35 yr-old and the oldest group 55 - 65 yr-old, which registered the same means, followed by the second oldest group (40 - 50 yr-old) (Figure 4 and 6). However, the boys group (≤ 5 yr) ranked third, whereas the group which ranked fourth was group 15 - 20 yr-old (Figure 4).

Aguilera., *et al.* [2] in a biomonitoring study in Spain, in a highly polluted area (mining and industries), in which they determined the arsenic and Cd, Cr, Cu, and Ni in urine samples of children and adolescents residing in this area, and of a reference group living in other less industrial areas in South Spain. They reported no significant differences in the concentration of metal compounds between the two groups, with the exception of Cd levels, which were significantly higher in the reference group. The main determinants were age, sex, area of residence and frequency of intake of certain food items (mainly fish and shell fish). Over all, results suggest that living in the first area (polluted) is not increasing current levels of exposure to certain metals among children and adolescents found in other urban areas of south Spain. Wadelsayed village is located near the Blue Nile River, which is one of the main sources of fish in the country and is village is very close to the oldest sugar factory in the country which was established 1963.

When comparing the concentration of Cd in males and females (same age- group) in Rigwa village (Figure 5), the data showed that the girls ≤ 5 yr. (0.289 ppm) manifested by far higher concentrations than the boys of the same age (0.089 ppm). Such a big difference between girls and boys needs more intensive investigation to justify these differences and perhaps also their expected consequences in girls from the physiological and toxicological point of view. Considering the oldest group in both sexes in Rigwa, male's urine showed higher Cd concentration (0.288 ppm) than females (0.119 ppm), which is 2.4x higher in males. Again, more explanatory studies must be conducted to justify this difference. Moreover, the concentrations of Cd, starting the age-group 15 - 20 yr-old showed a an increasing trend with the increase in age, except age group 55 - 65 yr-old in females (Figure 5).

The concentration of Cd, Wadelsayed village, again varied between and within each population. Regarding the males (Figure 3) the oldest age group (55 - 65 yr-old) showed a mean of 0.04 ppm. This was the lowest level of Cd among all tested age-groups in this village.

Regarding the males of Wadelsayed village (Figure 4), as in the Pb investigation [10], there was completely different picture in Cd concentrations in urine. The highest concentration was detected in age group 15 - 20 yr-old, followed by the young boys (≤ 5). The second oldest age group (40 - 50 yr-old) ranked third, whereas the group which ranked fourth was group 25 - 35 yr-old. The oldest group (55 - 65 yr-old) of the males ranked fifth. The differences between the males and females of this age-group of Wadelsayed were not significant (p = 0.01) (Figure 6).

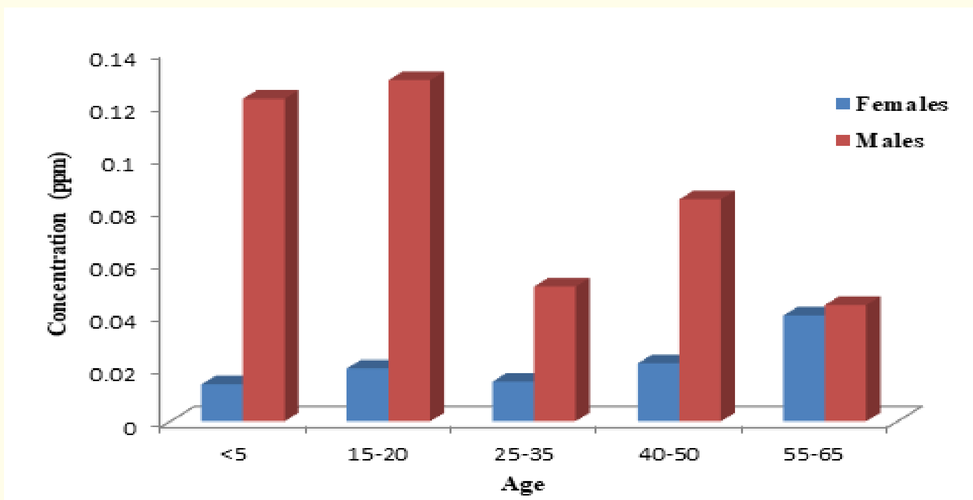

Figure 6: *Means of cadmium concentration (ppm) in males and females in Wadelsayed village.*

The Cd concentration in the males of Wadelsayed proved to be by far higher than that of the females in almost all age- groups (Figure 6). Taking the age group 40 - 50 yr-old males as an example, their average was 0.084 ppm, compared to that of the females (0.022 ppm; almost 4x). Another examples is age group 25 - 35 yr-old males with a mean of 0.051 ppm and that of the females was 0.015 ppm (> 3x). To complete the picture, also the age group 15 - 20 yr-old was higher in males (0.129 ppm) than in females (0.02 ppm; > 6x). Even in the children group, the males (0.122 ppm) registered higher Cd concentration than the females (0.014 ppm; > 8x; Figure 6). When comparing the concentration of Cd in all tested age-groups in the two villages, the data revealed high concentration in females of Rigwa village than their counterparts in Wadelsayed (Figure 5).

The translocation of some metals (K, Mg, Mn, Fe, Pb and Cd) in Nigeria was investigated by Mbuk., *et al.* [13] in soil in the presence of the herbicides paraquat (bipyridelium group) and glyphosate (OPs group) using surface soils samples. For paraquat, the mobility of Fe and Mn in soil was suppressed, while K mobility was enhanced. Glyphosate enhanced the translocation of Cd, Mg, Pb and K under similar treatment. These two herbicides are commonly used in the Sudan for controlling aquatic weeds in irrigation canals and other weeds in orchards. Both areas, Rigwa and Wadelsayed are agricultural areas, especially Wadelsayed, which is known for sugarcane plantations since early 1960s, cotton, groundnut, sorghum, wheat and vegetables.

Soils in some areas tend to have elevated amounts of one or more of the HMs. Food crops and especially vegetables grown on such soil, tend to accumulate substantial amount of HMs [14].

Conclusions

1. All collected urine samples showed the presence of Cd (from 0.04 to 0.289 ppm). This indicates that the populations in Wadelsayed and Rigwa villages were exposed to these HMs from their food, water, air, working places and/or other sources.
2. The concentrations varied within and between age-groups and sexes of the same village, and between the two villages.
3. The Cd concentration in urine of Wadelsayed village (accused of being polluted) males (from 0.044 to 0.129 ppm) was lower than that detected in urine of Rigwa (far from pollution sources) males (from 0.069 to 0.288 ppm).
4. Surprisingly, the concentration of Cd found in urine of children 5 yr. or less was higher than that found in both adult male and females in two the villages.

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