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Correlation between exposure to toxic heavy metals in fish, sediment and drinking water, and high incidence of prostate enlargement in two states of the Niger-Delta, Nigeria

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ABSTRACT

We studied the correlation between the chronic environmental exposure to polyaromatic hydrocarbons (PAHs) and six toxic heavy metals in the Niger Delta and the incidence of prostate enlargements in men. The field research was conducted in three communities in two states viz: Ondo and Akwa Ibom. Prostate gland enlargement in men 40 years and above was determined by rectal examination *in situ*, while levels of PAHs and metals were obtained in drinking water from boreholes, surface water (river), hand dug-out wells, rain water, sediment; and in five species of locally consumed fish by Gas chromatography (GC) and Flame Atomic Absorption spectrophotometry (FAAS), respectively. Results show high incidence rates of prostate enlargement in the two states: Ondo (combined rates of Igbokoda and Ilepete communities) at 39.4% and Akwa Ibom (Ibeno Community) at 33.3%. Both rates are much higher than those of World Health Organization world–wide (WHO) rates and the African rates of 14% and 11 to 12%, respectively, representing 178.5%/227.3% and 135.7%/175% increases, respectively. Correspondingly, levels of the six heavy metals (Ni, Cr, Cd, Pb, Mn and Co), were excessively high in fish and sediment samples in Ondo and in drinking water and sediment in Akwa Ibom, all surpassing WHO maximum permissible levels over 10-fold. However, PAH levels in all samples at the three locations in the two States were near absent. These results clearly suggest an exposure–response relationship, to the heavy metals as all volunteers who are domiciled in the communities for over twenty years, are primarily shallow-water fishermen and consume the fish they catch. Also, they all denied any close relative, dead or alive, with the disease. Without prejudice to genetic and/or lifestyle pre-disposition therefore, it is our conclusion that the six heavy metals may be implicated as causative agents maybe in synergy with “other” factors, in inducing the extremely high incidence rates of prostate enlargement we observed in the three communities of the two states of the Niger Delta.

Keywords: Toxic heavy metals, exposure, incidence, prostate enlargement, Niger-Delta.

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INTRODUCTION

The human health consequences of chemical pollution in the environment have been a source of prime public health concern for a very long time, especially in the Niger Delta region where crude oil exploration and production activities have been occurring for decades with their attendant oil spillages and effluent discharges.

That these spillages pose serious health risks to target populations, has never been in doubt, but it is the specific adverse health effects that are in debate. Several epidemiological reports have suggested strong correlation

between human exposures to crude oil components and skin follicular lesions, hyperkeratosis and possibly carcinoma (IARC, 1989), However, Nigerian geological crude oil, for example, Bonny Light Crude Oil (BLCO) has not yet been shown to induce or promote cancer in humans although there are reports of its probable carcinogenicity in laboratory animal studies (Oruambo et al., 2007).

Chemicals in the environment and/or work place are said to constitute the bulk of the agents or factors that cause cancer in humans and also pose risk of occurrence (Clapp et al., 2008). These include chlorinated organic pesticides, polychlorinated biphenyls, vinyl chloride, acetochlor and heavy metals such as cadmium, nickel, lead and arsenic which have been specifically implicated in prostate and breast cancer.

Also, living near hazardous waste dumping sites and oil fields/wells, contact with polycyclic aromatic hydrocarbons (PAHs) as in crude oil spills have been suggested to pose prostate and breast cancer risks. Karimi et al. (2012) reported in their study a positive association between trace elements and heavy metal levels in nails and hair with prostate cancer in Malaysian men.

Similarly, metal contamination in five fish species caught from the Mediterranean seas in Turkey was reported by Turkmen et al. (2008). This study probably emanated from a Food and Agriculture Organization (FAO)/WHO report in 2001 which published maximum permissible levels of heavy metals in fish caught in the Turkey seas, underscoring the potential cancer risks of heavy metals.

Chukwujinda (2012) reported differential heavy metal contents in some brands of biscuits consumed in Southern Nigeria.

In this study therefore, we aim to determine whether or not a correlation exists between the chronic consumption of fish and drinking water contaminated with any or all of the six heavy metals (so-called “six nasties”, that is, cadmium, chromium, nickel, lead, manganese and cobalt) and 16 PAHs, and the abnormal incidence rates of prostate enlargements in men 40 years and above as an “indicator” of the on-set of prostate cancer.

MATERIALS AND METHODS

The study-design of this field research was predicated on two pillars, that is, clinical/physical rectal examination of recruited volunteers (men, 40 years and above) by trained and qualified medical doctors; and instrumental analysis of tissue samples from five species of fish caught in the local rivers, and drinking water sampled from local boreholes, hand-dug wells and rain water as well as sea sediment.

Ethics

In order to comply with National/International ethical standards in human studies, advocacy visits to the traditional rulers, and mobilization were carried-out prior to actual examination during which true aims and procedure of the study were fully explained. Their consent was sought which all the volunteers gave willingly.

Temporary free clinic

To obtain a reasonable sample size, a temporary free clinic (TFC) was set-up at the local primary Health Care Centre during which free medical examination and free drugs were given as a *pri pro quo* for rectal examination, and focused symptom/sociological questionnaires were administered.

Parameters

Clinically enlarged prostate glands (as “indicator” of probable on-set of prostate cancer) were used in rectal examinations.
Six heavy metals, that is, Ni, Cr, Cd, Co, Mn, and Pb; and sixteen PAHs, that is, Naphthalene, Acenaphthylene, Acenaphthene, Fluorene, Phananthrene, Anthralene, Fluoranthene, Pyrene, Benz(a)anthralene, Chrysene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(a)pyrene, Indeno(1,2,3-cd)pyrene, Dibenz(a,h)anthracene and Benzo(g,h,i)perylene, were measured in five fish samples, sediment and drinking water by Gas chromatography linked to a soft-ware (GC) for PAHs, and flame Atomic Absorption Spectrophotometry (FAAS) – for heavy metals.

Sampling protocol

Samples for PAHs were collected from local river (sea) in glass containers while those for heavy metals in plastic containers. All samples were collected in the dry season; water and fish samples wee pre-digested with nitric acid for heavy metal analysis and for PAH, samples were suspended in distilled water and the sample containers were wrapped with aluminium foil to protect against photo-oxidation of the PAH.

All samples were stored at 4°C before transport to the laboratory.

Drinking water samples

Drinking water was collected in each location, that is, Ondo (Igbokoda and Ilepete) and Akwa Ibom (Ibeno), from hand-dug out wells and local boreholes as described above.

Fish samples

Samples of five species of fresh fish were bought from local fishermen as they brought in their catches. The fish samples were quickly cut-up and ample tissues were excised and treated as described above.

RESULTS

The concentrations of the six heavy metals we measured in drinking water, fish tissue and sediment samples, and PAHs levels are shown in Table 1

As shown, the 6 heavy metal concentrations in drinking water were all well below detection limit. Also, none of the 16 PAHs was detected. However, the heavy metal concentrations in fish and sediment samples are shown to be excessively higher in all five fish species than the

Table 1. Mean Concentrations of 16 PAHs and 6 heavy metals obtained in drinking water, sediment and fish tissue in Ondo State.

S/N	Sample identity	Ni	Co	Cd	Cr	Mn	Pb	PAH
Drinking water samples (mg/L)*								
1	Sample 1	BDL	BDL	BDL	BDL	0.084	BDL	
2	Sample 2	BDL	BDL	BDL	BDL	0.050	BDL	
3	Sample 3	BDL	BDL	BDL	BDL	BDL	BDL	
4	Sample 4	BDL	0.0312	BDL	BDL	0.044	BDL	
5	Sample 5	BDL	BDL	BDL	BDL	0.063	BDL	Below detection limit (BDL)
6	Sample 6	BDL	BDL	BDL	BDL	0.015	BDL	
7	Sample 7	BDL	BDL	BDL	BDL	0.005	BDL	
8	Sample 8	BDL	BDL	BDL	BDL	0.0011	BDL	
9	Sample 9	BDL	BDL	BDL	BDL	0.013	BDL	
10	Sample 10	-	BDL	BDL	BDL		BDL	
Fish samples (mg/kg)*								
1	Black Croaker	0.349	0.251	0.035	0.465	3.469	0.879	
2	Cat Fish	0.244	0.284	0.058	0.526	2.099	1.444	
3	Tilapia	0.302	0.229	0.061	0.427	0.308	1.022	Below detection limit (BDL)
4	White Croaker	0.273	0.315	0.062	0.426	2.188	0.680	
5	Periwinkle	0.325	0.425	0.072	0.518	2.952	0.968	
Sediment samples (mg/kg)*								
1	Sediment 1	1.016	1.416	0.069	0.370	12.505	1.810	
2	Sediment 2	0.837	1.372	0.082	0.349	12.248	1.918	Below detection limit (BDL)
3	Sediment 3	0.991	1.433	0.094	0.490	12.394	2.069	
4	Sediment 4	1.036	1.744	0.072	0.792	12.600	1.892	

BDL = Below detection limit. *Studies reported by FAO/WHO in 2001 suggested that permissible levels of cadmium (Cd) in foods/fish is 0.05 mg/kg, but in water, it is 0.003 mg/L, while for nickel, (Ni), 0.02 mg/L; chromium (Cr), 0.05 mg/L; lead (Pb), 0.01 mg/L; and manganese (Mn), 0.4 mg/L.

FAO/WHO standards.

Corresponding incidence of prostate enlargement in Ondo State

In Ondo state, the incidence rate of clinically enlarged prostate glands, as determined by rectal examination, shows that out of a total of 38 men examined 15 showed positive for enlargement, representing a 39.4% rate.

Statistics of percentage increases of both prostate enlargements and levels of heavy metals and PAHs were compared to WHO world-wide and National Incidence rates, and maximum allowable concentrations (MAC), respectively.

Our focus was to assess the environmental levels of PAHs and 6 toxic heavy metals and demonstrate a “correlation” between the chronic exposures to the very high levels of the heavy metals in particular and corresponding high incidence rates of prostate enlargement. This rate is excessive when compared to WHO’s world-wide rate of 14% (Cancer Res; UK and IARC, 2012), and an African rate of 11 to 12% (Chu et al., 2011) representing increases of 178.5 and 227.3%, respectively.

In Akwa Ibom State, correspondingly, the incidence rate of clinically enlarged prostate glands as judged by rectal examination, of men 40 years and above, was 33.3% that is, ten (10) of thirty (30) showed positive for significant enlargement. All ten were below the age of 60 years, while the youngest was 40 years old (Table 2).

DISCUSSION

Of all human cancers, prostate and breast/cervix are known to be most prevalent in men and women, respectively in developing countries, including Nigeria (Cancer Res., UK; IARC, 2012). Furthermore, both types of cancers are reported to be caused by a combination of genetic, hormonal, dietary and environmental factors (Cancer Res; UK; IARC, 2012).

Prostate cancer has been reported to be caused by chronic exposures to pesticides, herbicides, polyaromatic hydrocarbons (PAHs), and specific heavy metals, cadmium and chromium (Clapp et al., 2008; Turkmen et al., 2008). This is consistent with the link of cancers with exposures to carcinogenic PAHs and heavy metals,

Table 2. Concentrations of six heavy metals* and sixteen PAHs in drinking water (mg/l) in Akwa Ibom State, Niger Delta, Nigeria.

S/N	Sample identity	Ni (mg/L)	Mn (mg/L)	Cr (mg/L)	Cd (mg/L)	Pb (mg/L)	Co (mg/L)	PAH (mg/L)
1	Sample 1	0.468	0.140	0.919	0.143	1.009	0.655	0.010
2	Sample 2	0.434	0.115	0.854	0.138	0.951	0.673	0.001
3	Sample 3	0.443	0.124	0.716	0.126	0.957	0.596	0.003
4	Sample 4	0.417	0.102	0.799	0.140	0.852	0.564	0.001
5	Sample 5	<0.001	0.020	<0.001	<0.001	<0.001	<0.001	0.009
6	Sample 6	0.012	0.095	<0.001	<0.001	<0.001	0.005	0.005
7	Sample 7	0.432	0.065	0.815	0.135	0.820	0544	<0.001
8	Sample 8	0.430	0.104	0.696	0.123	0.665	0.614	0.007
9	Sample 9	0.404	0.099	0.748	0.134	0.731	0.569	<0.001
10	Sample 10	0.455	0.101	0.827	0.143	0.690	0.593	<0.001
11	Sample 11	0.041	0.009	<0.001	<0.001	<0.001	<0.001	<0.001
12	Sample 12	0.041	<0.001	0.076	<0.001	<0.001	<0.001	<0.001
13	Sample 13	0.023	<0.001	<0.001	<0.001	<0.001	<0.001	0.003
14	Sample 14	0.044	<0.001	<0.001	<0.001	<0.001	0.003	0.002
15	Sample 17	0.016	<0.001	<0.001	<0.001	<0.001	0.019	<0.001
16	Sample 18	0.043	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
17	Sample 19	0.027	0.254	<0.001	<0.001	<0.001	<0.001	<0.001
18	Sample 20	0.109	0.254	<0.001	<0.001	<0.001	<0.001	<0.001
19	Sample 21	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
20	Sample 22	0.024	<0.001	<0.001	<0.001	<0.001	0.052	<0.001
21	Sample 23	0.051	0.915	<0.001	<0.001	<0.001	<0.001	<0.001
22	Sample 24	0.048	0.951	<0.001	<0.001	<0.001	0.053	<0.001
23	Sample 25	0.069	0.054	<0.001	<0.001	<0.001	<0.001	<0.001
Heavy metals* & PAH in sediment (mg/kg) in Akwa-Ibom								
1.	Sample 15	1.290	34.99	<0.001	<0.001	<0.001	1.480	0.007
2.	Sample 16	1.330	27.31	<0.001	<0.001	<0.001	1.520	<0.001

*Studies reported by FAO/WHO in 2001 suggested that permissible levels of cadmium (Cd) in foods/fish is 0.05 mg/kg, but in water, it is 0.003 mg/L, while for nickel (Ni), 0.02 mg/L; chromium (Cr), 0.05 mg/L; lead (Pb), 0.01 mg/L; and manganese (Mn), 0.4 mg/L.

chromium, cadmium, arsenic, beryllium and lead (IARC, 1989; Karimi et al., 2012).

In fact, cadmium has been associated with prostate cancer, especially in farmers, for a long time now. The mechanism is proposed to be via geno-toxicity as was reported for nickel, chromium and cadmium that are said to induce oxidative stress in DNA and cause DNA damage (Turkmen et al., 2008).

Studies reported by FAO/WHO in 2001 suggested that permissible levels of cadmium (Cd) in foods/fish is 0.05 mg/kg, but in water, it is 0.003 mg/L, while for nickel (Ni), 0.02 mg/L; chromium (Cr), 0.05 mg/L; lead (Pb), 0.01 mg/L; and manganese (Mn), 0.4 mg/L.

Our data shows that these heavy metals occurred at levels far in excess in drinking water, sediment and fish we sampled in the communities under study, which may be causative agents of the equally excessive high incidence rate of prostate enlargement in these communities.

Furthermore, Karimi et al. (2012), reported the following: that exposure of men to poisonous heavy metals like lead, cadmium, arsenic, mercury and uranium was shown to cause severe metabolic imbalance from the consumption of contaminated predator fish; the heavy metal toxicities were shown to be key to develop prostate cancer; prostate mortality was found to be strongly contributed by cadmium; and finally that contrary to previous studies, no significant association was found between lifestyle habits, that is, alcohol use, smoking and obesity and prostate cancer in Malaysian men.

To put these figures in proper perspective shows increased incidence rates over WHO's world-wide rate, which is 14% (Cancer Res, UK; IARC, 2012) of 178.5%; and National/Nigerian rate, which is 11 to 12% (WHO, 2013), of 22.3% in Ondo; and 135.7% and 175% in Akwa Ibom State, all respectively.

In Tables 1 and 2, we show the environmental levels of the six heavy metals; we measured in five species of fish caught in the local rivers, sediment and drinking water in all three communities in the two states.

Correspondingly, increases in the incidence rates of clinically enlarged prostate glands in men 40 years and

above, we reported o be 39.4 and 33.3% in Ondo and Akwa Ibom States, respectively.

As the two sets of data clearly show, there is a link between increased incidence rates of prostate enlargement in men 40 years and above in Ondo and Akwa Ibom States and excessive environmental levels of Ni, Cr, Cd, Pb, Mn and Co in the media already described.

This conclusion is justified by the fact that all the men who showed enlarged prostate glands are domiciled in the three communities and have been chronically–exposed to the heavy metals contaminated drinking water and fish for most of their lives.

Therefore without prejudice to genetic or lifestyle factors, we attribute the high incidence rate to equally high heavy metal levels.

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