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Original Research Article

Maternal exposure to carbon monoxide in the first trimester (7-13^{+6} weeks) of pregnancy in the core Niger Delta

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ABSTRACT

Background: Irrespective of the fact that the Niger Delta was known for its environmental pollution, neither organized environmental assessment nor human biomonitoring, including that of carbon monoxide (CO) had been performed in the region. The aim of the study therefore was to establish the severity of maternal impact on exposure to CO in the first trimester of pregnancy by quantifying the exhaled CO concentrations (ECOC) and to assess the effect of maternal age, body mass index (BMI) and parity on the severity of the impact.

Methods: The study was of cross-sectional design carried out at the Rivers State University Teaching Hospital (RSUTH) in Rivers State. 490 consecutive pregnant women in the first trimester were recruited from the antenatal clinic from January 2021 to January 2022. Gestational age was estimated with the aid of ultrasound scan. Demographic, social and obstetric characteristics were taken. Exhaled carbon monoxide concentration (ECOC) was measured with the aid of a smokerlyzer. Data was analyzed, using the statistical package for social sciences (SPSS) version 25.0 (Armonk, NY) software. Ethical approval was obtained from the RSUTH ethics committee.

Results: The mean value of ECOC 3.25±2.51 ppm was more than that obtained in other studies. Out of the total 490 patients that were assessed, 335 (68.37%) had mild impact from CO exposure (ECOC=1-3 ppm), 129 (26.33%) – moderate impact (ECOC=4-6 ppm) and 26 (5.31%) had severe impact (ECOC=more than 6 ppm). Moderate and severe impacts were more prominent in women of age groups 25-39 years and the differences in various age groups were statistically significant [X^2=20.671, $p<0.036$, 95% CI (0.032, 0.040)]. Patients with higher BMI were more likely to have moderate and severe impact than those with lower BMI- 6 (33.33%) and 4 (22.22%) out of the 18 patients with class III obesity had moderate and severe impacts respectively. The differences in the impact at various BMI were statistically significant [X^2=20.671, $p<0.001$, 95% CI (0.001, 0.002)]. There was inverse relationship between parity and the severity of the impact and the differences in various parity groups were statistically significant [X^2=10.580, $p<0.012$, 95% CI (0.101, 0.113)]. There was also a paradoxical finding of 3 smokers having only mild impact.

Conclusions: The mean value of ECOC 3.25±2.51 ppm was more than that obtained in other studies in non-pregnant women. Mild, moderate and severe impact from maternal CO exposure were established with the moderate and severe impact more prominent at maternal ages of 25-39 years, at higher BMI and at lower parity.

Keywords: Maternal exposure, Carbon monoxide, First trimester, Pregnancy, Niger Delta

INTRODUCTION

The Niger Delta area in Nigeria is situated in the Gulf of Guinea between longitude 50E to 80E and latitudes 40N to 60N. It is a home to more than 20 million people drawn from nine states namely Rivers, Bayelsa, Akwa Ibom, Cross River, Delta, Abia, Edo, Imo and Ondo with the first two States called the 'Core Niger Delta'. The region produces over 90% of Nigeria's foreign earnings through oil and gas exploration and production activities. It therefore plays host to most of the upstream and downstream oil related and non-oil related industries that release tons of pollutants including carbon monoxide (CO) into the environment.

The environmental terrain in the Delta led to series of scientific research, the most notable ones of which were the World Bank study of the region and the environmental assessment of Ogoniland in the core Niger Delta which delivered a catalogue of devastation due to oil pollution in the region.[1,2] Ogoniland which is one of the heavily polluted regions in Rivers State was tagged 'a region of environmental disaster.[2]

Generally, sources of CO pollution in the Delta were tobacco fumes, generators, firewood, kerosene, bush and refuse burning, fire outbreaks, barbecues, burning of fossil fuels in old vehicles, crude oil and gas industry (three refineries, oil wells, flow stations and gas flaring, crude oil and condensate spills, vapours from crude and refined oil storage, processing and transportation facilities, petrochemical plants and gas liquefaction plants).[3]

CO is an inorganic colourless, odourless and non-irritating gas produced from incomplete combustion of carbonaceous compounds. It is a primary pollutant as it is emitted from a source directly into the atmosphere. It enters into the body primarily through inhalation, though there is also nominal endogenous production of the gas. CO inhalation was the most common cause of poisoning in the industrialized world and in many other countries. It was the leading cause of the fatal poisoning reported.[16] It can cause multi-organ dysfunction and frequently necessitating admission to intensive care units.

In pregnancy, maternal impact of CO pollution ranges from headaches at carboxyhaemoglobin (COHb) levels of 5-20% to maternal death at CO Hb levels of >66%.[4] Maternal exposure to the gas during the period of ontogenesis is associated with abnormalities of organs and systems including the central nervous system, skeleton and face, and the heart.[4-7] Other toxic effects include intrauterine growth restriction, preterm labour, intrauterine fetal death, and sudden infant death.[7-11]

In contrast to what happens in the developed world of Europe, part of Asia and North America, organized air quality assessment and human medical biomonitoring was not practiced in Nigeria.[3] There were however pockets of monitoring by multinational companies and university academics in their immediate are of interest. The ambient and indoors air concentrations of CO in the Delta ranged from 0 ppm to 191 μg/m^3 but in places within 60-200 metres from crude oil flow stations, the concentrations range from 100 to 5320 μg/m^3.[12]

Therefore, irrespective of the knowledge of the sources of CO production in the Niger Delta and its impact on mother and fetus, there was no data or register on the prevalence of its poisoning and its clinical presentations. There was no data on maternal nor paternal exhalation of CO and consequently, no knowledge of maternal and fetal carboxy-hemoglobin concentrations and associated health impact.

Aim

The primary aim of the study therefore was to establish the severity of the impact of maternal exposure to CO in the first trimester of pregnancy in the core Niger Delta by quantifying the levels of her exhaled CO. The secondary goal was to assess the extent of modification of the detrimental impact of CO by maternal demographic, social and obstetric characteristics, namely age, BMI, smoking status and parity.

METHODS

The study was of cross-sectional design carried out at the Rivers State University Teaching Hospital (RSUTH) in Rivers State, which is one of the States in the core Niger Delta area of Nigeria. The study population included all the pregnant women attending the antenatal clinics in the first trimester of pregnancy up till 14 weeks from January 2021 to January 2022. Consecutive attendants were counselled about the research project and informed consents were obtained.

The exclusion criteria were pregnant women with physical disabilities such as deafness and dumbness, critically ill patients, as well as those with a history of ongoing mental illness/retardation (because of the difficulties associated with taking history from the patients), uncertain date of last menstrual period with no ultrasonographic estimation of gestational age between 11-14 weeks of gestational age. Gestational age was estimated with the aid of dating scans in the first trimester of pregnancy. Demographic, social and obstetric characteristics including age, education, drinking and smoking status, BMI and parity were taken.

Measurement of maternal exhaled carbon monoxide

A hand-held instrument called Smokerlyzer has been used to measure the concentration of CO in expired air especially in smokers.[14] It displays CO in part per million (ppm), concentrations of maternal carboxyhaemoglobin (MCOHb) which is synonymous with the concentration of oxygen that is displaced by CO (% CO Hb) and fetal carboxyhaemoblobin (fCOHb) which, is synonymous with the percentage of oxygen that is displaced by CO in fetal circulation (%fCOHb) but in the present project, we were interested in the concentrations of exhaled CO.

Clinical research has demonstrated that a useful relationship between carbon monoxide and carboxyhaemoglobin is obtained after a short period of breath-holding. Smokerlyzer only directly measures the exhaled CO concentration while MCOHb and fCOHb are calculations based on clinical evidence. CO ppm - % CO Hb calculation was taken from Jarvis et al.[15]

$$COHb = 0.63 + 0.16\ (EC50)$$

Here EC50 is the concentration of CO in ppm that is expired after inhalation as measured with a smokerlyzer (breath test).[13] CO ppm - %fCOHb calculation was taken from Gomez et al.[16]

Although women in the core Niger Delta almost do not smoke, they are perpetually exposed to CO because of the presence of several sources of the gas in the Delta. We therefore hypothesised that they were likely to be affected by the gas just as women who smoke are. The smokerlyzer (Figure 1) was therefore used to measure the concentration of exhaled CO in the women and indirectly, the concentrations of MCOHb and fCOHb were given by the machine.

Figure 1: Smokerlyzer.

Taking the breath test

Attach a breath sampling D-piece to the smokerlyzer and then insert new Steri Breath mouthpiece into the end of the D-piece. Turn on the monitor by pressing the power button once and press the breath test symbol on the screen or to cancel the breath test, press the arrow-up figure on the smokerlyser. Inhale and hold breath for the pre-set 15 second countdown. A beep will sound during the last three seconds of the countdown. Blow slowly into the mouthpiece, aiming to empty lungs completely. The ppm and equivalent %COHb and/or %FCOHb levels will rise and hold onscreen. On the Micro-Smokerlyzer, when the test is finished, ♫Δ⊟ will appear at the bottom of the screen (Figure 1).

The severity of maternal exposure to CO was assessed, using the data from Table 1a and b which came with the smokerlyzer - %COHb in Table 1a for maternal COHb concentration while CO ppm and %fCOHb in table 1b for maternal exhaled CO and fCOHb respectively were used as reference ranges for comparison.

Green zone

This is where a mother really needs to be. It means she does not exhale more than 3 ppm of CO in her breath and that corresponds to less than 2% CO in her blood. Most people have a small amount of CO in their breath, this is due to the air quality around them.

Gray zone

Having a reading in this zone would indicate a light smoker or a non-smoker breathing in air of poor quality.

Red zone

Having a reading in this zone indicates that the person may well be a regular smoker with higher levels of CO in the blood; in the present study, we have extrapolated that to significant environmental pollution since almost all the study population does not smoke.

Determination of the sample size

The outcome measures in the study were the incidence of different measures of severity of exposure to CO and the modification of the impact by maternal age, parity, BMI and smoking status. Therefore, the sample size was calculated using the sample size formula for a cross-sectional study with a categorical outcome.

$$n = Z\alpha/22 \times P(1-P)/d^2$$

Where Zα/22 is standard normal deviate at 95% confidence interval which is 1.96, P is expected proportion in population based on previous studies. Since there were no figures in the past for the assessed parameters in the study, 50% was used in the calculation of the sample size and d is absolute error or precision equal to 0.05.

Therefore,

$$N = 1.962 \times 0.5\frac{1-0.5}{0.052} = 3.8416 \times 0.5 \times \frac{0.5}{0.0025} = 384.16$$

The required number of patients for the study was therefore 384.16. Giving allowance for attrition rate of 10%, the final sample size for the study was given by.

$$10/100 \times 384 + 384 = 422.56$$

Therefore, the number of patients to be recruited for the study was 423. We were however able to recruit 490 patients.

Statistical analysis

Data was collected on a special pretested proforma and then transferred into an excel file where they were cleaned and fed into statistical package for the social sciences (SPSS) version 25.0 (Armonk, NY) software for analysis. Simple proportions were used in the descriptive analysis. Quantitative data were summarized and presented as mean and standard deviation while qualitative data were presented as numbers and percentages. Comparison of related variables was conducted, using the Chi-square (X^2) and the p values. When the p value was less than 0.05, the differences between the variables were said to be statistically significant. When an expected count was lower than 5 in a cell, Fisher exact test was used.

Table 1: Derivation of the %COHb and %fCOHb from CO ppm on the basis of clinical evidence.[13]

a			b	
CO ppm	**%COHb**		**CO ppm**	**%FCOHb**
30	5.43	Red zone	20+	5.66
29	5.27			
28	5.11		19	5.58
27	4.95			
26	4.79		18	5.09
25	4.63			
24	4.47		17	4.81
23	4.31			
22	4.15		16	4.53
21	3.99			
20	3.83		15	4.25
19	3.67			
18	3.51		14	3.96
17	3.35		13	3.69
16	3.19		12	3.40
15	3.03		11	3.11
14	2.87		10	2.83
13	2.71		9	2.55
12	2.55		8	2.26
11	2.39		7	1.98
10	2.23	Gray zone	6	1.70
9	2.07		5	1.42
8	1.91		4	1.13
7	1.75			
6	1.59	Green zone	3	0.85
5	1.43			
4	1.27		2	0.57
3	1.11			
2	0.95		1	0.28
1	0.79			

Ethical consideration

The study was carried out in compliance with the international ethical guidelines for biomedical research involving human subjects. Ethical approval was obtained from the RSUTH ethics committee. Verbal consents were obtained from all the women that were enrolled in the study. All the information that was collected from individual patients was available for clinical use and for the research purposes. Privacy rules were maintained and confidentiality was observed at all levels of dealing with patients' data.

RESULTS

Demographic, obstetric and general characteristics

Four hundred and ninety (490) women who were 11-14 weeks pregnant were recruited for the study. Details of their demographic parameters namely age, education, alcohol consumption and cigarette smoking status, parity, BMI and marital status were as shown in Table 2.

Table 2: Demographic, obstetric and general characteristics of the patients.

Demographic obstetric and general characteristics	Frequency	%
Maternal age, years (n=490)		
20-24	17	3.47
25-29	145	29.59
30-34	212	43.27
35-39	103	21.02
40-44	9	1.84
45-49	4	0.82
Education (n=490)		
Secondary	73	14.90
Tertiary	417	85.10
Alcohol (n=488)		
No	370	75.82
Yes	118	24.18
Yes	118	24.18
Smoking (n=490)		
No	487	99.39
Yes	3	0.61
Parity (n=483)		
0	230	47.62
1 to 2	223	46.17
3 and above	30	6.21
BMI (n=472)		
≥40.0 (class III obesity)	18	3.81
18.5-24.9 (normal weight)	80	16.95
25.0-29.9 (overweight)	218	46.19
30.0-34.9 (class I obesity)	107	22.67
35.0-39.9 (class II obesity)	49	10.38
Marital status		
Married	490	100
Not married	0	0

Measures of severity of exposure to CO

The impact of maternal exposure to CO was measured by the mean value of exhaled CO which was 3.25±2.51 ppm and the actual concentration of maternal exhaled CO as shown in Table 3.

Table 3: Degrees of severity of exposure to carbon monoxide (n=490).

Degrees of severity	Exhaled CO concentration, (ppm)	Frequency	%
Mild	1-3	335	68.37
Moderate	4-5	129	26.33
Severe	More than 5	26	5.31

The effect of demographic, obstetric and general characteristics of the patients on the impact of maternal exposure to CO

The effect of maternal age on the impact of her exposure to CO

The modification of the severity of maternal exposure by her age was as shown in Table 4.

The effect of maternal smoking on the severity of her exposure to CO

The severity of maternal exposure to CO was also associated with maternal smoking habit as shown in Table 5 and it was classified into mild, moderate and severe impact.

The effect of maternal BMI on the severity of her exposure to CO

The severity of exposure to CO was also assessed with respect to different classes of BMI. The results were as shown in Table 6.

The effect of maternal parity on the severity of her exposure to CO

The severity of the exposure to CO was also assessed with respect to parity. The results were as shown in Table 7.

Table 4: Relationship between maternal age and CO levels (n=490).

Maternal age group years	No. of patients associated with different degrees of severity of exhaled CO. n%(col)/(row)			Total N (% col)	X^2	P value 95% CI
	Mild (1-3 ppm)	Moderate (4-6 ppm)	Severe (>6 ppm)			
20-24	17 (5.07)/(100)	0 (0)/(0)	0 (0)/(0)	17 (3.47)	20.671	0.036* (0.032, 0.040)
25-29	100 (29.85)/(68.97)	37 (28.68)/(25.52)	8 (30.77)/(5.52)	145 (29.59)		
30-34	139 (41.49)/(65.57)	65 (50.39)/(30.66)	8 (30.77)/(3.77)	212 (43.27)		
35-39	66 (19.70)/(64.08)	27(20.93)/(26.21)	10 (38.46)/(9.71)	103 (21.0)		
40-44	9 (2.69)/(100)	0/(0)	0/(0)	9 (1.84)		
45-49	4 (1.19)/(100)	0/(0)	0/(0)	4 (0.82)		
Total	335 (68.37)	129 (26.33)	26 (5.31)	490 (100)		

*Significant

Table 5: Relationship between maternal smoking and CO levels.

Maternal smoking	Severity of exhaled CO. ppm n (%)			Total	X^2	P value 95% CI
	1-3	4-6	>6	N (Col)		
No	332 (68.17)/(99.10)	129 (26.49)/(100)	26 (5.34)/(100)	487 (88.39)	1.397	0.632 (0.623, 0.642)
Yes	3 (100)/(0.90)	0 (0)/(0)	0 (0)/(0)	3 (0.61)		
Total	335 (68.37)	129 (26.33)	26 (5.31)	490 (100)		

Table 6: Relationships between maternal BMI and CO levels.

Maternal BMI	No. of patients associated with different degrees of severity of exhaled CO. n% (col)/(row)			Total N (% col)	X^2	P value 95% CI
	Mild (1-3 ppm)	Moderate (4-6 ppm)	Severe (>6 ppm)			
18.5–24.9 (normal weight)	56 (17.23)/(70.00)	24 (19.51)/(30.00)	0 (0)/(0)	80 (16.95)	31.68	0.001 (0.001, 0.002) *
25.0–29.9 (overweight)	146 (44.92)/(66.97)	63 (51.22)/(28.90)	9 (37.50)/(4.13)	218 (46.19)		
30.0–34.9 (class I obesity)	83 (25.54)/(77.57)	20 (16.26)/(18.69)	4 (16.67)/(3.74)	107 (22.67)		
35.0–39.9 (class II obesity)	32 (9.85)/(65.31)	10 (8.13)/(20.41)	7 (29.17)/(14.29)	49 (10.38)		
≥40.0 (class III obesity)	8 (2.46)/(44.44)	6 (4.88)/(33.33)	4 (16.67)/(22.22)	18 (3.81)		
Total	325 (68.86)	123 (26.06)	24 (5.08)	472 (100)		

*Significant

Table 7: Relationships between parity and CO levels.

Parity	No. of patients associated with different degrees of severity of exhaled CO. n%(col)/(row)			Total N (% col)	X^2	P value 95% CI
	Mild (1-3 ppm)	Moderate (4-6 ppm)	Severe (>6 ppm)			
0	158 (47.59)/(68.70)	62 (49.60)/(26.96)	10 (38.46)/(4.35)	230 (47.62)	10.580	0.012* (0.101, 0.113)
1-2	148 (44.58)/(66.37	59 (47.20)/(26.46)	16 (61.54)/(7.17)	223 (46.17)		
3 and above	26 (7.83)/(86.67)	4 (3.20)/(13.33)	0 (0)/(0.00)	30 (6.31)		
Total	332 (68.74)	125 (25.88)	26 (5.38)	483 (100)		

*Significant

DISCUSSION

The study was prompted by the popular believe that the core Niger Delta area of Nigeria was plagued with environmental pollution. The sustained impact of maternal exposure to CO was measured by the concentrations of maternal exhaled CO which was classified into mild, moderate and severe. The classification was adapted from the hitherto attained norms that came with the instrument Smokerlyzer Bedmont and was based on previous studies.[14,15]

The mean age of the participants in the study was 31.5682± 4.49 years. Majority of the patients 357 (72.86%) were in the age category of 25-34 years; that was followed by 103 (21.02%) at 35-39 years of age, indicating that most women had their children in the normal reproductive age limits (Table 2).

The impact of maternal exposure to CO was measured by the mean value of exhaled CO concentration (ECO) which was 3.25±2.51 ppm and the actual ECOC. The mean ECO concentration in the present study with the study population primarily non-smokers was more than that obtained in other studies, also in non-smokers from London where it was 1.9 ppm, Thailand - 2·25 ppm, Japan - 1.2 ppm and 1.5 ppm in two different studies, Singapore - 1.9 ppm and Poland - 1.1 ppm.[20,21,28-31] It was less than the mean CO levels in other studies in non-smokers, where it was 3.6 ppm in Indiana, USA and Turkey, and 4.2 ppm in Taiwan.[22,32,33] The difference between the present study and the other ones was that they were done outside pregnancy while the present study was carried out during pregnancy.

Out of the total 490 patients that were assessed, 335 (68.37%) had mild impact from CO exposure (ECOC=1-3 ppm), 129 (26.33%) – moderate impact (ECOC=4-6 ppm) and 26 (5.31%) had severe impact (ECOC=more than 6 ppm). The impact was different at different gestational age groups 20-24 to 45-49 years and the differences were statistically significant [X^2=20.671, p<0.036, 95% CI (0.032, 0.040)].

The least affected were women in the age groups 20-24, 40-44 and 45-49 years of which none of them had moderate nor severe impact on exposure to CO. Moderate impact was more common in women at 30-34, 35-39 and 25-29 years of age in descending order and it occurred in 30.66%, 25.52% and 26.21% of the patients in each of the age groups respectively. Severe exposure was more common at 35-39, 25-29 and 30-34 years-age groups at which it occurred in 9.71%, 5.52% and 3.77% of the total population in each age group respectively.

There were 3 smokers out of the total 490 patients (0.61%) (Table 5). Smoking exposes people to a high concentration of CO.[17] In the WHO report, the CO concentration in tobacco smoke was around 4.5% (45,000 ppm) and smokers inhale air with a concentration of about 400–500 CO ppm during smoking.[18] Generally, without potential air pollution, the exhaled CO concentration would be expected in a range of 1–4 ppm in non-smokers and 2–18 ppm in smokers.[19]

Contrary to what was expected, the 3 smokers in the present study had mild impact on exposure to CO. Even though Jarvis et al reported that exhaled CO measurement could distinguish smokers from non-smokers, they mentioned that a few smokers could not be identified due to the fact that they did not inhale the smoke very deeply.[20] Long period since the last cigarette could also be an explanation for the low exhaled CO in the smokers. The carboxyhemoglobin half-life for a healthy person breathing air is approximately 4 hours.[23] A patient who stops smoking for a sufficiently long period, could exhale similar concentration of CO like non-smokers. Furthermore, smokers could lower their CO exposure by reducing the puff volume, the puffs smoked and the tendency and depth of inhaling.[17, 23-27]

Out of the total 472 patients that had their exhaled CO concentration and BMI taken, 325 (68.86%), 123 (26.06%) and 24 (5.08) of them exhaled 1-3 ppm (mild exposure), 4–6 ppm (moderate exposure) and more than 6 ppm CO (severe exposure) respectively and the differences between the severity of the impact at various BMI groups were statistically significant [X^2=20.671, p<0.001, 95% CI (0.001, 0.002)].

Exhaled CO of mild, moderate and severe category was least prominent at class III obesity [8 (44.44%) out of the 18 patients investigated at that BMI], class I obesity [20 (18.69%) out of the 107 investigated with that BMI] and at normal BMI (0 out of the 80 patients investigated with that BMI] respectively. Mild impact was most prominent in women with class I obesity [83 (77.57%) out of the 107 investigated with that BMI], while the moderate and severe impacts were most prominent at class III obesity [6(33.33%) and 3 (22.22%) respectively out of the 18 patients investigated with that BMI]. It was therefore quite interesting that severe impact on exposure to exposure to CO was prominent at high BMI - class II obesity [7 (14.29%) out of the 49 with that BMI) and class III obesity.

Out of the total 483 patients that had their exhaled CO concentration and parity assessed, 332 (68.74%), 125 (25.88%) and 26 (5.38%) of them had mild, moderate and severe impact respectively on exposure to CO and the differences in the severity of the impact in various parity groups were statistically significant [X^2=10.580, p<0.012, 95% CI (0.101, 0.113)].

Maternal exhaled CO of mild impact was least prominent at para 1-2 [148 (66.37%) out of the 223 patients at that parity] while the moderate and severe categories were least prominent at para 3 and above [4 (13.33%) and 0 (0%) respectively out of the 30 patients at that parity. Maternal exhaled CO was most prominent at para 3 and above [26 (86.67%) out of 30] for mild impact, para 0 [62 (26.96%) out of 230] for moderate impact and para 1-2 [6 (7.17%) out of 223] for severe category of exhaled CO.

Limitations

The limitation of the study lied in the fact that only maternal exhaled CO was assessed. MCOHb and fCOHb were not assessed simultaneously with the exhaled CO with a view of verifying their relationship and their similarity in impacting maternal and fetal health. There was also the need to assess the mean value of exhaled CO in association with different maternal demographic, social and obstetric characteristics.

CONCLUSION

The mean value of ECOC 3.25±2.51 ppm was more than that obtained in other studies. Out of the total 490 patients that were assessed, 335 (68.37%) had mild impact from CO exposure (ECOC=1-3 ppm), 129 (26.33%) – moderate impact (ECOC=4-6 ppm) and 26 (5.31%) had severe impact (ECOC=more than 6 ppm). Moderate and severe impacts were more prominent in women of age groups 25-39 years, at higher BMI, and at lower parity. There was also a paradoxical finding of 3 smokers having only mild impact of maternal CO exposure.

Recommendations

There is need for the introduction of a unified Niger Delta air quality assessment and also a universal screening program for the impact of maternal exposure to CO in the Niger Delta. That will go a long way identifying those regions that are worse affected and women that are most at risk of the exposure.

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