

# Mercury exposure and associated reported menstrual disorders among women in artisanal and small scale gold mining in Nyang'hwale district, Geita, Tanzania

## Abstract

**Background:** Out of the workers involved in small scale mining activities in Tanzania, women are 30-50%. Normally use mercury to recover gold from the ores. This practice may cause a wide range of health impacts including reproductive defects in reproductive hormone and an ovulation which may result to menstrual disorders in women working in artisanal and small scale gold mining.

**Objective:** The study aimed to assess occupational exposure to mercury and associated menstrual disorders among women working in artisanal and small scale gold mining in Nyang'hwale District, Geita.

**Materials and methods:** The study was descriptive cross sectional study design. Simple random sampling technique was used to obtain 170 of women working in ASGM and 99 of women who were teaching primary schools. Data on the proportion of menstrual disorder were collected using face to face administered questionnaire and analyzed using descriptive statistics. The Chi square test and Binary logistic regression were performed for association between mercury exposure and menstrual disorders. 95% confidence Interval expressed in  $P = 0.05$  or  $P < 0.05$  was used. CVAAS was used to analyze mercury concentration level in urine.

**Results:** The mean Age of the participants was  $33.6 \pm SD$  and the mean of menarche age was  $15.26 \pm SD$ . The proportion of menstrual disorders in the exposed group was significant higher than that in the non exposed group (OR 1.5; 95% CI 1.160 – 1.876 and  $P = 0.001$ ). The proportion of menstrual disorders in exposed group was (67%) and non exposed group (46%). The proportion of dysmenorrhea in the exposed group was found statistical significant higher than that in the non exposed group (OR 2.7; 95% CI 1.579 – 4.489 and  $P = 0.0001$ ) and the proportion was (38%). The mean mercury levels in urine were

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41.3ug/L for exposed group and 2.04ug/l for non exposed group respectively. Out of 21 urine samples, 6 (28.6%) exceeded the Maximum World Health Organization (WHO) acceptable level of 50 ug/L.

**Conclusion and recommendation:** The findings generalized that women who are exposed to occupational mercury have higher risk to report the problems of menstrual disorders. The district council stakeholders should create awareness to mining community, that mercury used for amalgamation process to extract gold may be associated with menstrual disorders and other reproductive health defects among the women working or living nearby the mining areas.

**Keywords:** mercury exposure, menstrual disorders, artisanal and small scale gold mining, Tanzania

## Definition of terms

**Menstruation** refers the flow of blood and tissue lining the uterus through the vagina. Most sources note that flow happens for 5 days (range 2-7 days), every 28 days (range 21-35days).

**Menstrual disorder** refer to an abnormal condition in a woman menstrual cycle such as; when menstrual periods that occur less than 21 days or more than 35 days apart, missing three or more periods in row, and menstrual flow that is much heavier or lighter than usual.

**The symptoms of Menstrual disorders** includes; (of duration or length), hyper- or hypomenorrhoea, polymenorrhoea or oligomenorrhoea, dysmenorrhoea, amenorrhoea, menorrhagia, prolonged menses, intermenstrual bleeding.

**Dysmenorrhea** Pain (e.g. cramps) or discomfort related to menstruation, either primary (associated directly with menstruation) or secondary (related to an underlying gynecological disorder).

**Amenorrhoea** Absence menstrual periods: stops getting period for at least 3 months and is not pregnant.

**Oligomenorrhoea** infrequent menstrual periods: Periods that occur more than 35 days apart.

**Menorrhagia** heavy menstrual periods: Also called excessive bleeding.

**Prolonged menstrual bleeding:** Bleeding that exceeds 7 days in duration on a regular basis.

**Polymenorrhea:** Frequent menstrual periods occurring less than 21 days apart.

**Hypomenorrhoea:** Shortened menstrual bleeding of less than 2 days in duration.

**Intermenstrual bleeding:** Episodes of bleeding that occur between periods, also known as spotting.

**Artisanal and Small-Scale Gold Mining (ASGM)** refer to Small groups of people engaged in low-cost, low-tech, labor intensive excavation and processing of gold.

**Mercury (Hg)** is a heavy silver liquid metal. When heated, it turns into invisible vapors. Even at room temperature, it releases toxic vapors.

**Amalgamation** refer to the process of mixing mercury with gold-containing materials, forming a mercury-gold amalgam which is then heated, vaporizing the mercury to obtain the gold.

## Background

Artisanal and small-scale gold mining (ASGM) is undertaken by individuals or groups with limited equipment and often informally without mineral right.<sup>1</sup> Artisanal and small scale mining (ASGM) is increasingly common in many parts of the world with more than 30 million active artisanal miners in more than 55 countries.<sup>2</sup> It is estimated that over 30% of all ASGM activity worldwide is undertaken by women but depending on the region this may be much greater.<sup>3</sup> In Africa, ASGM workforce comprises not less than 40-50% women.<sup>4</sup> Female miners can take part in all aspects of mining, digging, crushing, transporting, sorting, processing and trading.<sup>5</sup> In Tanzania alone, is estimated 0.5 to 1.5 million of informal miners, of whom 30-50% are women<sup>2</sup> were involved in mining activity they normally use mercury to recover gold from the ore. In gold smelting or amalgam they use their bare hands when handling mercury, which expose them to risk both from mercury vapour and direct contact through skin. In fact, the number of artisanal mining sites is expanding in many regions of Tanzania, particularly around Lake Victoria and in the central and southwestern regions of the country;<sup>2</sup> Artisanal and small scale mining activities are largely concentrated in rural areas that have very little infrastructure, and the individuals undertaking informal mining generally lack education, training, management skills and essential equipment for safe mining practices.<sup>2</sup> In mining process, mercury is used to extract gold from ore in artisanal and small scale gold mining. Approximately 40% of this mercury is lost during the initial concentration of amalgamation stages of the gold mining process and the remaining 60% is released directly into the atmosphere when the Hg amalgam is burned at the end of the purification process, exposing miners to inorganic-mercury poisoning either via the respiratory tract as vapor or through the skin by contact.<sup>6</sup> Thus resulting into millions of small scale miners, infants, children, women of child bearing age (potentially pregnant), and breast-feeding women who are working or living in ASGM communities be at risk of mercury exposure.<sup>7</sup>

Chronic mercury exposure may seriously result to menstrual cycle disorders, arising from interference with the part of the brain which controls reproduction (hypothalamo-pituitary-gonadal axis). Epidemiological studies have shown the harmful effects of mercury vapour on the central nervous system; the excess of ovulatory troubles in a group of occupationally exposed women has been interpreted as an

indirect consequence of this effect on the pituitary hypothalamic axis.<sup>8</sup> Mercury is poorly absorbed through the skin and gastrointestinal tract by less than 1%, also is efficiently absorbed through the lung by 80% to 85%,<sup>9</sup> the dissolved vapour remains in the blood long enough to cross the blood brain barrier where it is oxidized and eliminated only very slowly.<sup>10</sup> Necropsy studies of occupationally exposed to mercury have found high concentrations of mercury in the pituitary, thyroid, and brain; these is evidence that mercury persists in these tissues for many years, hence the mercury that accumulates is biologically active able to interfere with endocrine or reproductive function.<sup>10</sup> The occurrence of these hormonal problems may lead to the development of various chronic health problems, including menstrual cycle irregularities and the continually occurring over a long periods may result in early onset of menopause.<sup>11</sup> But the evidence shows that the women exposed to mercury are reported to have the highest prevalence of menstrual cycle disorders, compared to non mercury exposed group according to some studies done in China, Italy and Colombia (17%, 47% and 59% respectively).<sup>8,12,13</sup> In European and North American studies, it was found that over one-half of the women of reproductive age and about 30 to 90% of menstruating women report lower abdominal and lower back pain associated with the menstrual cycle due to mercury vapour exposure.<sup>12</sup> The findings suggest that globally there is high prevalence of menstrual disorders such as dysmenorrhea, prolonged menstrual periods, irregular periods, heavy flow periods and premenstrual syndrome.<sup>14</sup> The World Health Organization reported that 18 million women of reproductive aged perceive their menstrual bleeding to be excessive. Such disorders have economic consequences in terms of health care costs due to the consumption of expensive hormonal drugs and laboratory tests.<sup>15</sup> In developing countries approximately 4 to 8% of women report having menstrual periods longer than 7 to 8 days and excessive, profuse or heavy bleeding 4 to 9% and prevalence of excessive bleeding was reported to be higher, increasing from 8% to 27%.<sup>16</sup> Nigeria and Ethiopia also reported the prevalence of menstrual cycle disorders among the women in reproductive age to be 19% and 46% respectively.<sup>17</sup> Although the menstrual disorder is associated with psychosocial problem, life style, health status; also may be associated with mercury exposure.<sup>18,19</sup> Studies done in Tanzania on mercury exposure and associated health effects among ASGM focused on mercury intoxication and neurological symptoms, tremors, stomatitis, gingivitis memory loss, vision impairment, insomnia, emotional instability and other health symptoms.<sup>2,20,21</sup> So far, little has been documented on mercury exposure and associated menstrual disorders in women working in artisanal and small scale gold mining. This study based on, determined the proportion of women with menstrual disorders, determined the concentration of mercury level in urine and associated menstrual disorders among women in artisanal and small scale gold mining in Nyang'hwale District.

## Material and methods

### Study design and setting

The cross sectional study design was used for assessed exposure to mercury and associated menstrual disorders among women in artisanal and small scale gold mining in Nyang'hwale District, Geita, Tanzania. Nyang'hwale District is one of the five Districts in Geita region in Tanzania, where intensive artisanal and small scale gold mining activities are conducted and most of women are self employed in gold mining activities, directly exposed to elemental mercury vapour.

## Selection of participants

We recruited 269 women of age group between 18 – 44 years old. Whereby 170 were women selected in artisanal and small scale gold mining as exposed group, currently working in artisanal and small scale gold mining for at least one year in amalgamation process and those who carry out other activity around the mining area like heating gold ores were included in the study; and 99 participants were women selected from primary schools (Teachers) as non exposed group who were selected 5km away from the village where artisanal and small scale gold mining was being conducted. Women who were pregnant, any type of diagnosed pelvic pathology (fibroids, pelvic inflammatory disease), and lactating mothers were excluded to participate in this study.

Four study wards were selected purposively out of twelve wards due to availability of the villages where women were working intensively in artisanal and small scale gold mining in all mining stages. Then one village from each ward was selected purposively due to criteria of the elements included in the study as predefined to obtain 4 villages. Then the women who were working in artisanal and small scale gold mining whose fulfill the inclusion criteria were selected using simple random sampling technique using lottery method; and the same sampling technique was used to select non exposed group (Primary teachers) to obtain the total number of sample size 99 from 16 primary schools.

## Data collection procedures

Data on the proportions of menstrual disorders was collected using semi structured questions which were adapted from Modified gynecologist questionnaire for assessing Menstrual cycle disorders.<sup>22-24</sup> The questionnaire includes questions about demographic and occupational data, history of exposure to mercury or other chemicals, history of gynecological and disease, the approximate interval of days (menstrual length) between first to next menstrual cycles (include Oligomenorrhea, Amenorrhea, Polymenorrhea, Hypomenorrhea) the average days of the menstrual bleeding, menstrual flow as slight or excessive bleeding (Menorrhagia,) than usual by assessing the approximate number of sanitary napkins used daily, prolonged menstrual bleeding, shortened menstrual bleeding, intermenstrual bleeding and on symptoms of menstrual cycle disorders the questionnaire included the questions on physical symptoms like excessive abdominal pains, severe menstrual cramps. The questionnaire contained the questions on assessing other factors contribute to menstrual disorders like consumption of alcohol, smoking habit, post exposure to pesticide and habit of performing physical exercises.

We recruited three research assistants who had a post health professional background and were serving as health workers in Nyang'hwale district. The assistants were oriented to research concept, protocol, data collection tools (questionnaire) and procedures of urine collection.

## Procedures for urine collection and analysis

First morning urine samples were collected as recommended by World Health Organization guideline for mercury analysis in urine sample.<sup>23</sup> From 21 respondents who were selected by random systematic sampling strategy by skipping 12 respondents after each sampled participants. 15 and 6 urine samples were collected from

exposed and non exposed groups respectively. The urine sample was collected in sterile plastic containers (100 ml size) and 50ml of urine were collected and the containers were kept closed until ready for analysis. Participants were asked to open the container at the time of urine collection and close it immediately after urine collection to avoid touching inside the container or cap to avoid contamination.<sup>25-27</sup> Urine samples were stored in cold box at collection site and transported to the District hospital laboratory where they were refrigerated (4°C) until transport to Government Chemist Laboratory for analysis.

Analysis of urine was performed by Flow Injection Cold Vapour Atomic Absorption Spectrometry (CVAAS).<sup>28</sup> The digestion of urine was carried out then the sample solutions were subjected to CVAAS for mercury determination. The mercury levels in the urine from analytical results were compared with World Health Organization (WHO) standards. Analysis was performed for three weeks by Government chemistry Laboratory Authority at Lake Zone.

## Data analysis

Descriptive statistics was done for demographic characteristics of the participants, menstrual disorders among the women who were exposed to mercury and non-exposed to mercury the data presented in tables. The difference in mean of mercury level between two groups were determine using Mann Whitney U test. Multivariate logistic regression and bivariate analysis using chi square test were used to find the association between mercury exposure and menstrual disorders; P value equal to 0.05 or less ( $P < 0.05$ ) was considered statistically significant to show the association between exposure to mercury and menstrual disorders among the women in ASGM. The prevalence odds ratio (OR) which was used to measure the association between mercury exposure and menstrual disorders.

## Ethical clearance

Ethical clearance was provided by the Muhimbili University of Health and Allied Sciences (MUHAS) Ethical Committee, issued on 30<sup>th</sup> May 2019. Permission to conduct the study at the field was requested and provided by the Nyang'hwale district medical officer. Written informed consents were obtained from the participants after being informed on the operation and application of the study findings. Confidentiality of the respondents was ensured at all stages of the study.

## Results

### Social demographic characteristics of the study participants

The study had 269 respondents who were in the age group between 18 – 44 years with mean age 34 (7.476) whereby the mean age of the exposed group was 35(7.868) and non exposed group 31(6.117). According to occupation, (63%) of the women working in artisanal and small scale mining as exposed group and (37%) were primary school teachers as non exposed group, these groups were very energetic and productive. With regard to marital status (56%) of non exposed group were married and the difference was statistical significance. Regard to education level, the majority of exposed group had no education by (54%) followed by (42%) who had primary education level, whereby (100%) of primary school teachers had a tertiary education level (Table 1).

**Table 1** Socio-demographic characteristics of women working as ASGM and Primary School Teachers in Nyang'hwale District (N= 269)

Variables	Overall Frequency	Overall Frequency %	Exposed Frequency	Exposed Frequency %	Non exposed Frequency	Non exposed Frequency %	P value %
Age (years) Mean (SD)	33.64	(7.476)	35	(7.868)	31.3	(6.117)	
Weight(kg) Mean (SD)	65.29	(12.610)	65.3	(12.594)	65.2	(12.703)	
<b>Marital status n (%)</b>							
Single	70	26	39	22.9	31	31.3	
Married	105	39	50	29.4	55	55.6	
Cohabitation	27	10	21	12.4	6	6.1	
Divorced	45	16.7	42	24.7	3	3	
Widow	22	8.2	18	10.6	4	4	0.0001
<b>Education level n (%)</b>							
No education	92	34.2	92	54.1	0	0	
Primary school	72	26.8	72	42.4	0	0	
Secondary school	6	2.2	6	3.5	0	0	
Tertiary level	99	36.8	0	0	99	100	0.0001
<b>Occupation</b>							
Exposed	170	63.2	170	100	0	0	
Non exposed	99	36.8	0	0	99	100	0.0001

### Occupational exposure to mercury (Table 2)

**Table 2** Occupational exposure to mercury among the women in ASGM and non-exposed group (Primary school teachers) in Nyang'hwale District

Variables	Variable categories	Frequency	%
Work category	Amalgamation	160	59.5
	Heating gold ores	10	3.7
	Teaching	99	36.8
Not used PPE	Miners	170	63.2
	Special room	22	8.2
	Inside the house	88	32.7
Storage of Mercury	Others place	4	1.5
	Don't know	56	20.8
	Damp site	2	0.7
Disposal of empty containers	Burning around the mining site	140	52.0
	Disposal haphazardly	28	10.4

### The proportion of menstrual disorders among women

Exception for bleeding spotting before and after menstrual period or after sexual intercourse, proportion of women with menstrual

disorders was found to be statistically significant higher in exposed group as compared to non-exposed group (Table 3).

**Table 3** The menstrual disorders among the women in artisanal and small scale gold mining and women teaching primary schools in Nyang'hwale District

Variables	Exposed (N=170)		Non exposed N=99		P -Value
	Frequency	%	Frequency	%	
Amenorrhea	61	35.9	21	21.2	0.01
Oligomenorrhea	47	27.6	1	1	0.0001
Polymenorrhea	24	14.1	7	7.1	0.05
Dysmenorrhea	64	37.6	14	14.1	0.0001
Menorrhagia (Excessive bleeding)	52	30.6	14	14.1	0.003
Bleeding spot before and after the menstrual period	31	18.2	20	20.2	0.75
Blood spot after sexual intercourse	15	8.8	7	7.1	0.65
Slight Bleeding	3	1.8	0	0	0.001
Prolonged duration	32	18.8	7	7.1	0.001
Hypomenorrhea	15	8.8	2	2	0.001

### Mercury level in urine

(Table 4) Mean mercury level in urine of the participants was (30.06µg/L), and the range was 72.883ug/l to 0.247ug/l. The mean mercury level in urine for exposed group was statistically significantly higher (41.33ug/L) compared to non exposed group (2.04 ug/L) and P = 0.0001.

About (40%) of the miners group had mercury level above the maximum acceptable level and (40%) of them were at action level who were tested for mercury levels in urine, exceed the maximum acceptable level provided by WHO as shown in Table 5 above. Amongst the non-exposed group who tested for mercury levels in urine, (83%) were at normal level (less than 5ug/l) as shown in Table 5.

**Table 4** Urine Mercury levels (ug/L) in selected participants N=21

	Mean (SD)	N	Mean Rank	Sum of Rank	P-value
All participants	30.06 ug/l				
Occupation					
Miners	41.33 ug/l	15	14	210	
Non Miners	2.04ug/l	6	3.5	21	<0.001

Mann Whitney U Test for difference in means between two independent groups was used

**Table 5** Distribution of mercury level in urine measurements in comparison to WHO standards

Levels (µg/L)	Mercury level in Urine (µg/L) Exposed N = 15		Mercury level in Urine (µg/L) non exposed N =6		Status WHO standards
	Frequency	Percentage	Frequency	Percentage	
Less than 5ug/l	0	0	5	83.3	Normal
5- 19 ug/l	3	20	1	16.7	Alert level
20 – 49ug/l	6	40	0	0	Action level
Greater than 50ug/l	6	40	0	0	Maximum Acceptable level

### Association between mercury exposure and menstrual disorders

The menstrual disorders were more likely among the women who were in exposed group compared to non exposed group; and there was statistically significant association between mercury exposure and menstrual disorder; for example dysmenorrhea was more likely among women exposed to mercury (OR 2.7; 95% CI 1.579 – 4.489 of and P= 0.0001) (Table 6).

The result from binary logistic regression shows that mercury level in urine was the most predictor for menstrual disorders after adjusted with other predictors as shown in Table 7. The results indicate that the increase in mercury exposure there is an increase the probability of menstrual disorders problem. This mean that mercury in urine is statistically significant associated with menstrual disorders compared to other predictors (OR 4.787; 95% CI 1.213-25.106 and P = 0.05) (Table 7).



**Table 6** Association between mercury exposure and menstrual disorders among women working in ASGM in Nyang'hwale Geita

Variables	Exposed (N=170)		Non exposed N=99		P -Value	OR	95% CI
	Frequency	%	Frequency	%			
Amenorrhea	61	35.9	21	21.2	0.01	1.7	1.101 - 2.599
Dysmenorrhea	64	37.6	14	14.1	0.0001	2.7	1.579 – 4.489
Menorrhagia	52	30.6	14	14.1	0.003	2.2	1.266 -3.695
Polymenorrhea	24	14.1	7	7.1	0.005	2.0	0.893-4.464

Chi square test ( $\chi^2$ ); P< 0.05; OR is odds ratio, and 95% CI is 95% confidence interval

**Table 7** Logistic regression shows the association between mercury level in urine and menstrual disorders among women working in ASGM in Nyang'hwale District

Variables	$\beta$	SE	Wald	P value	OR (CI of 95%)
<b>Menstrual disorders</b>					
Uses of family planning	-0.751	1.504	0.249	0.6	0.472(0.025 -9.000)
Body physical exercise	-3.905	2.441	2.56	0.1	0.020(0.000 -2.408)
Exposed to pesticide	-0.399	1.819	0.048	0.8	0.671(.019 -23.700)
BW decreases	-0.576	2.067	0.078	0.8	0.562(.01 -32.310)
BW increases	0.397	1.871	0.045	0.8	1.487(.038-58.241)
Hg level urine	1.566	0.845	3.431	0.05	4.787(1.213-25.106)

Logistic regression, OR is odds ratio, and 95% CI is 95% confidence interval

## Discussion

This study demonstrates that the proportion of menstrual disorders among the exposed group who were exposed to mercury used in the process known as amalgamation was statistically significant compared to non exposed group. The proportion of menstrual disorders among exposed group was (67%), while in non exposed group the proportion of menstrual disorders was (46%) (Table 3). This findings was consistent to the studies on mercury exposure and menstrual disorders in China, Italy and Colombia, which show that women who were exposed to mercury have the higher prevalence of menstrual disorders 17%, 47%, and 59% respectively.<sup>8,12,13</sup> However the proportion of menstrual disorders in this study (67%) was found to be slightly higher than those in Colombia (59%). These could be contributed by following factors; longer working hours, most of exposed groups 63.2% were working above 8 hours. Also longer working duration, whereby 51% of exposed group had been working for 2-3 years thus may result to increase mercury dose intake. Due to most of exposed group 63.2% were not using personal protective equipments (PPEs) to protect themselves from direct exposure to mercury and last improper storage and disposal of empty mercury containers were by 32.7% of mercury was stored inside the living house, and 52% of empty containers of mercury were burned around the mining area thus may lead to increase the concentration of mercury exposure (Table 2). These factors might have contributed to the increase dose response relationship toward the menstrual disorders among the exposed group. In this study the menstrual disorders was found to be statistically significant higher in exposed group as compared to non-exposed except for bleeding spot before and after the menstrual period and blood spot after sexual intercourse was found not statistically significant different between the exposed group and to the non exposed group. The proportion of dysmenorrhea was found to be statistically

significant higher among the exposed group (38%) than to the non exposed group (14%) as compared to other menstrual disorders (Table 3). This findings was consistent to the study conducted in China among the women working in lump factory and exposed to metallic mercury also found the prevalence of dysmenorrhea to be higher in exposed group than that in the non exposed group compared to other menstrual disorders.<sup>12</sup> Also the higher proportion of Polymenorrhea and oligomenorrhea were found statistically significant higher among exposed group compared to non exposed group in the study conducted in Italy among women worked in lamp factory.<sup>8</sup> The mercury vapor which is normally produced in any industrial process it was found to have effect in reproductive hormones which may result to menstrual disorders and other reproductive outcome in women working with elemental mercury. Also according to the study conducted in Colombia among the women in artisanal gold mining; the findings shows that the exposure to elemental mercury during the process of gold mining has an association with a higher prevalence of menstrual cycle irregularity.<sup>13</sup> The findings also was supported by the experimental study of all chemical forms of Hg administered to animals has shown that the result in disturbances in menstrual cycle and inhibition of ovulation.<sup>29</sup> The study conducted on occupational exposure to mercury in female dentist in United State of America also found the evidence that mercury accumulates in the brain, pituitary, and thyroid, that it disrupts ovulation in animals, and that women exposed to mercury tend to experience abnormal menstrual cycles.<sup>10</sup> The results generalized that women who are exposed to mercury have higher risk of reporting the problem of menstrual disorders compared to non exposed women.

Amenorrhea, dysmenorrhea and menorrhagia were found statistically significant higher among the exposed group compared to non exposed group. This results supported by the study conducted

in China among the females exposed to mercury vapour found the prevalence of dysmenorrhea was significantly higher than that to the control group. The prevalence of an abnormal menstrual cycle, abnormal duration of menstrual bleeding, and abnormal of menstrual bleeding in the exposed group was higher than that in the control group.<sup>12</sup> The menstrual disorders like dysmenorrhea was found to be statistically significant higher to mercury exposure (OR 2.7; 95% CI 1.579–4.489 and P=0.0001) (Table 6), hence from the result, there is an association between exposure to mercury and the menstrual disorders. This result also was supported by the study conducted in China among the females exposed to mercury vapour found that Dysmenorrhea may be a useful biomarker for assessing female exposure to mercury occupationally.<sup>12</sup> The findings shows that the mean mercury level in the urine (30.1µg/L) (Table 4) was lower than that found in the study conducted in Handeni and Chunya respectively.<sup>20,21</sup> It can be explained that the mean of mercury level in the urine were found from the lower level 0.27ug/l which was obtained from the non exposed group and the highest level was 72.883ug/l to the exposed group. This may be due to the difference in frequency of mercury used in the amalgamation process because women in mining area were not involved in amalgamation process as their daily activity. Despite the fact that, mercury use in this study area is low, there were women who were found with mercury levels exceeding the allowable levels. In this study we found that the maximum urinary mercury level of 72.88µg/L to a woman who was 44 years old used to store the mercury at home and involved in the amalgamation process for 5 years. While comparing to the study conducted in Handeni,<sup>21</sup> the exposed miners with maximum urinary mercury levels (74.7µg/L) who had worked in extraction, amalgamation process and burning amalgam for 7 years. The exposed group in this study was found with the urine mercury levels above (World Health Organization) WHO maximum allowable levels 40% of the urine samples tested by CVAAS exceeded WHO standard; and 40% of tested sample were found to the action level (Table 4). This results is slightly similar to the study conducted in Handeni Tanga found 47.6% of the urine samples tested by CVAAS exceeded WHO standard.<sup>21</sup> The mean of mercury level in exposed group was statistically significant difference from the non exposed group. This results is consistence to the study conducted in Chunya which found the Urinary mercury concentrations for exposed group were higher than the referent group.<sup>17</sup>

The result from binary logistic regression shows that mercury level in urine was the most predictor for menstrual disorders compared to the other predictors like the uses of modern family planning, body physical exercise, post exposure to pesticide, body weight increased and body weight decreased. When  $\beta$  value (coefficient value) is positive, OR>1 this indicates that the increase of mercury exposure is an increase for the probability of reporting menstrual disorders problem among women working in artisanal and small scale gold mining. This means that mercury in urine is statistically significant associated with menstrual disorders (OR 4.8; 95% CI 1.213-25.106 and P = 0.05) (Table 7). This findings was consistence to the study conducted in China among the females exposed to mercury vapour also observed a trend of increase prevalence of menstrual abnormality with the increase level of mercury exposure.

### Study limitations and mitigations

Information bias, is one of the limitations due to the nature of the study the respondent were more likely to provide wrong information for different reasons like fear of disclosing the information. Lead to spending more time to explain clearly to them on the aims and benefits of the study. Hence it was easy for them to understand before

a respondent was given the consent. Since the study was a cross sectional study design, it involved collection of information at a single point in time to assess the exposure and the outcome; it could not determine the causal-effect relationship between exposure to mercury and menstrual disorders.

### Conclusion

The findings generalized that women who are exposed to occupational mercury have higher risk to report the problems of menstrual disorders compared women who are not exposed to occupational mercury. The cohort study should be conducted in order to establish the causal effect relationship between mercury exposure and menstrual disorders, because there is still limited scientific information on mercury exposure and reproductive health effects in women occupationally exposed to mercury.

### Consent for publication

Not applicable.

### Availability of data and material

The data sets used and analyzed during the study are available and still under analysis for subsequent publications but will be available upon request from authors.

### Authors' contributions

SCK designed the study, conducted data collection, did data analysis and interpretation of findings, wrote and approved the manuscript. SM and JM provided technical inputs to improve designing the study, supported data analysis, read improved and approved the final manuscript write up.

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### Conflicts of interest

The authors declare that there was no conflict of interest.

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