A REPORT ON INDOOR AIR POLLUTION MONITORING STUDY IN KILIMANJARO REGION

Submitted to

TaTEDO

Prepared by:

TANZANIA INDUSTRIAL RESEARCH AND DEVELOPMENT ORGANIZATION (TIRDO)
P.O. BOX 23235
Dar es Salaam, Tanzania
Tel: +255-22-2666034/2668822
Fax: +255-22-2666034
Email: tirdo@intafrica.com
www.tirdo.org

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ABBREVIATIONS

DiSEDC	District Sustainable Energy Development Cluster
HUD	Hai Uduru
HNR	Hai Ndronga
HNK	Hai Nkuu sinde
HNS	Hai Nshara
HOFPS	Hai open fire place stoves
HWA	Hai Wari
HTSWS	Hai Three Stones Wood Stoves
IAP	Indoor Air Poluution
Mg/m3	Milligram per meter cubic
OSHA	Occupational Safety and Health Administration
PEL	Permissible Exposure Limit
RMA	Rombo Mamsera
RMAH	Rombo Maharo
RMJ	Rombo Manda juu
RME	Rombo Mengeni-aleni
RSH	Rombo Shimbi
RKI	Rombo Kitasha
ROFPS	Rombo Open fire place stoves
RTSWS	Rombo Three Stones Wood Stoves
TaTEDO	Tanzania Traditional Energy Development and Environment Organization
TIRDO	Tanzania Industrial Research and Development Organization
TSP	Total Suspended Particulate Matter
WHO	World Health Organization

1.0 INTRODUCTION

The Worldwide prevailing energy crisis (fuel wood in particular) has brought attention to TaTEDO and other energy experts (Institutional organizations) to search for ways of conserving whichever form of energy available and exploiting the various alternative technologies taking into consideration the environmental implications. TaTEDO is a Tanzanian non profit organization based in Dar es Salaam, whose objectives include the promotion of renewable energy and wood fuel technologies and practices. Also it supports and undertakes applied researches, studies and development of sustainable modern energy technologies in the field of renewable energy systems.

Recently, TaTEDO has implemented the ongoing project of improved wood stoves with chimney "Okoa stoves" to community members of Hai and Rombo districts in Kilimanjaro region. The proposed project was aimed at improving standard of living by minimizing IAP and use of fuel wood in the named two districts with a future plan to extend the project to other districts in Tanzania. Okoa wood fuel stoves are clean and efficient in burning wood with chimneys to provide draft for more efficient combustion and to remove smoke from the kitchen environment.

The rising rural population and the dependence of the rural low income groups on the wood stoves for cooking, heating and lighting have created a need to improve the efficiency of wood stoves. Therefore, in order to narrow the gap between the rising fuel-wood needs of the growing population and the limited afforestation capacities; the conservation of household energy through the utilization of more efficient wood stoves is of paramount importance. By introducing a new design of stove which is more efficient on energy utilization will reduce IAP together with money serving on the low income group while solving deforestation problem.

Combustion of wood materials has been associated with IAP and health-related problems such as incidences related to respiratory disorders and eye infections.

Wood smoke from cooking fire produces a poisonous cocktail of particles and chemicals that bypass the body's defenses and more than doubles the risk of respiratory illnesses such as bronchitis and pneumonia (WHO, 1984; 1987). The impact on individuals to these harmful gases depends both on the level of pollution and the time spent in cooking, amount of smoke inhaled, stage of development and any pre-existing health conditions.

The exposure is higher when cooking is done inside the house without partition and especially when there is poor ventilation. Particularly, combustion of wood in poorly vented kitchens using poorly functioning stoves leads to release of very high concentrations of suspended particulate matter and poisonous gases (Jyoti et al., 2000; WHO, 1999).

In view of the above, TaTEDO assigned the Tanzania Industrial Research and Development Organization (TIRDO) to undertake a study in order to determine the level of reduced indoor air pollution due to the use of okoa stove in households and establish the linkages with people's health so as to either advocate for its increased and/or undertake more search for further improvement.

2.0 MAIN OBJECTIVE

To establish the level of indoor air pollution in households using biomass fuel in Rombo and Hai districts and examine the relationship between biomass fuel exposure and the associated health effects.

The Specific objectives of this exercise were:

- To determine the concentrations of CO, CO_2, NO, NO_X and Suspended Particulate matter (SPMs) from combustion of wood fuel cooking technologies used in Rombo and Hai districts.
- To assess the effectiveness of the improved firewood stoves to lower exposure of IAP and improve the health perception and quality of life.

3.0 SCOPE OF WORK

The study was centred mainly in Hai and Rombo districts in Kilimanjaro region and involved the use of designed IAP questionnaire (drafted TaTEDO questionnaire) which was reviewed and adjusted accordingly by TIRDO expert to enable data collection before the field work started. The Consultant led a team of three TaTEDO staff in undertaking field survey for data collection particularly on how to take IAP measurements. Measurements to determine the levels of indoor air pollution and suspended particulate matter (SPM) were taken within the households. The study was limited to only 87 households using improved wood stoves with chimney which were given codes numbers and/or three stones fire place

in Hai and Rombo districts instead of 100 households as was indicated in TaTEDO's ToR. Equally, the traditional cooking stoves were also tested for their performance so as they were to be used as a reference point of energy improvement. The targeted indoor air pollutant gases were CO, CO_2, NO and NO_X and particulate matter. Secondary data on peoples' health status was expected to be collected from Hospitals and Heath Care Centers within visited villages. Unfortunately, such kind of information was not gathered and therefore excluded from this study.

4.0 METHODOLOGY

4.1 Data Collection

Pre-designed questionnaire was utilized to collect information that constituted the household details (demographic data, educational levels, source of income and IAP awareness), description of the kitchen, stoves condition and details of households' health status from the visited households. A detailed analysis of questionnaires and field observation lead to the establishment of respective efficiency and a comparative performance of targeted stoves.

Two measuring equipments were used to collect pollutant gases emission values and total suspended particulate matter in order to determine their levels and extent of cooks' and other family members exposure to IAP. During measurements, Combustion Gas Analyzer and Microdust pro were placed at a distance of 0 to 2 meters from the stove perimeter and at a height of 0.5 to 1 meters respectively. The stoves' pollution measurements were taken within that range because is usually where cooks stand while cooking and also a relatively the breathing zone of the mothers (and accompanying children) while in the kitchen. At each point, seven readings were taken by Combustion Gas Analyzer within the named ranges and used to represent the mean values of each respective point. The recording time for each reading was after every five minutes.

In the field, TaTEDO staff and DSEDC representatives were imparted with tactics and knowledge on data collection procedures (methodology) in order to improve accuracy and consistency of the collected data. The participation of TaTEDO staff was necessary for facilitating the survey undertaking and for meeting continuity and capacity building for similar project activities in the future. It was also important for DiSEDC and other TaTEDO

field staff from Kilimanjaro to participate in the field session since they were deemed important in providing some typical interventions based on their local perspectives. This is due to the fact that field staff and DiSEDC are in those areas on a full time basis, so they were in a position of providing the necessary support and guidance to the households whenever a problem emerges. Participating households were introduced on the importance of undertaking such a survey in their premises. The introduction included the importance of undertaking the survey so as to gather helpful information pertaining wood stoves in their households. Benefits such as reduction of deforestation and the associated negative impacts to the environment; and reduction of smoke in their kitchens were emphasized.

4.2 Data Analysis

All answered IAP questionnaires were analyzed by Statistical Package for Social Sciences (SPSS) whereas, emission data done by a spreadsheet and the levels of emissions obtained were compared with the Occupational Safety and Health Administration's Permissible Exposure Limits (OSHA PELs) and WHO standards to determine the levels of compliance. These stardards used to suppliment the unavailable local standards.

5.0 LIMITATIONS OF THE STUDY

- The IAP study was supposed to cover 100 households by testing wood stoves technologies used within community members in Kilimanjaro region. Unfortunately, the days and budget allocated by TaTEDO (the client) to undertake such a study were inadequate to cover the intended number of households in the two districts. Therefore, only 87 households were assessed.
- The survey also failed to obtain targeted secondary data on the health status of the stoves' users due communication barrier between TaTEDO sub offices at Moshi and the identified Health Care Centers.
- Equipment default. Microdust Pro (Casella Cel) failed to recognize both rechargeable and un-rechargeable batteries but was active once connected to electric cables. The device default forced field team to bend a bit against their methodology by taking particulate matter measurements only to those households found having electricity (power supply).

6.0 FINDINGS AND DISCUSSION

6.1 Findings from IAP Questionnaires

A total number of 87 households using wood stoves technologies were visited during the study at Hai and Rombo districts. Out of 87 households, 68 were using improved wood stoves with chimney (Okoa stoves) and the rest 19 were using traditional three stones fire place.

Figure 1: TaTEDO staff using questionnaire to collect some information from one of the household members using Okoa stove

Profiles of Hai and Rombo districts were explored by looking at the five main areas of interest which included (i) the demographic data of households visited at Hai and Rombo districts; (ii) people's awareness on IAP; (iii) location of kitchen; (iv) adequacy of ventilation; (v) cooking (kitchen) practices; (vi) condition of the stoves and (vi) households' respiratory disorders and other diseases related to IAP.

6.1.1 Demography of Households visited at Hai and Rombo Districts

From the sampled 87 households a total of 482 people were categorized in four major groups of children; youths; adults and elders. Further, sex was also used to differentiate the named four major groups in which 208 were males and 274 were females. The study findings revealed that 162 of household members were children; 115 were youth; 151 adults and the rest 54 were elders.

6.1.2 People's Awareness on Indoor Air Pollution (IAP)

During the study people's awareness on the issue pertaining to IAP were also assessed. More than 64.4% of interviewed household members were not aware on issues pertaining IAP. This lack of awareness can be attributed to their low educational level as revealed by analysed questionnaires in which 80% of them were having only primary school education.

6.1.3 Location of Kitchen

Three possible locations of kitchen were identified. These were: inside the main/living house (with full, partial or without separated walls), outside the main/living house and in the open space outside the main living house. Based on each tested stove type (Figure 2), 58.2% of the households using improved wood stoves had their kitchens located outside the main/living houses, while 37.3% had their kitchens located inside the main/living houses (with either full, partial or without separation walls). 4.5% of the households had their kitchens located in the open space. This implies that less than half of the households surveyed using improved wood stoves with chimney have kitchens located inside the main/living houses.

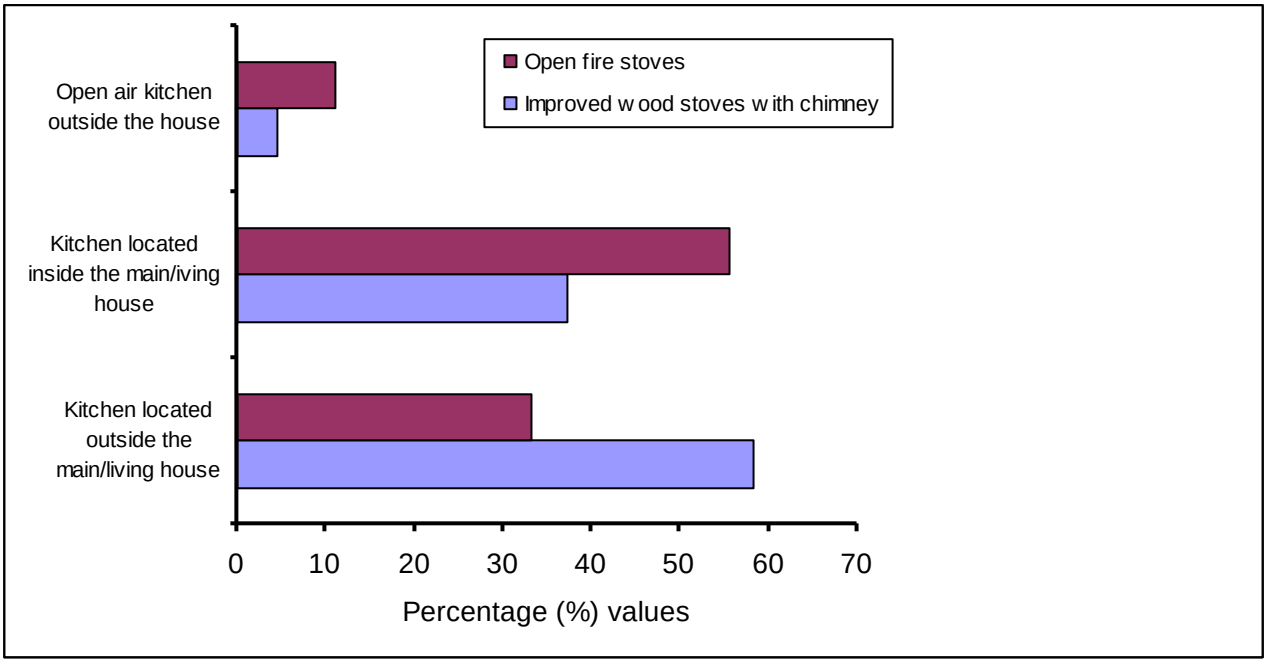

Figure 2: Location of kitchen

6.1.4 Adequacy of Ventilation

Kitchens with adequate ventilation have improved air quality due to dilution of pollutants from the cooking stoves. The result shown in Figure 3 on adequacy of ventilation was

measured based on the consultant's judgment of the kitchen environment and surroundings. 37.7% of tested improved wood stoves were located in the adequately ventilated place, meaning that they either had enough space in the kitchen and fresh air could flow freely across the cooking area or the kitchen was in the open space outside the main house where emissions could be drawn or driven away easily by the surrounding air passages. The other 37.8% stands for improved wood stoves tested in moderately well ventilated kitchens and the remaining 24.5% for kitchens in the poorly ventilated kitchen.

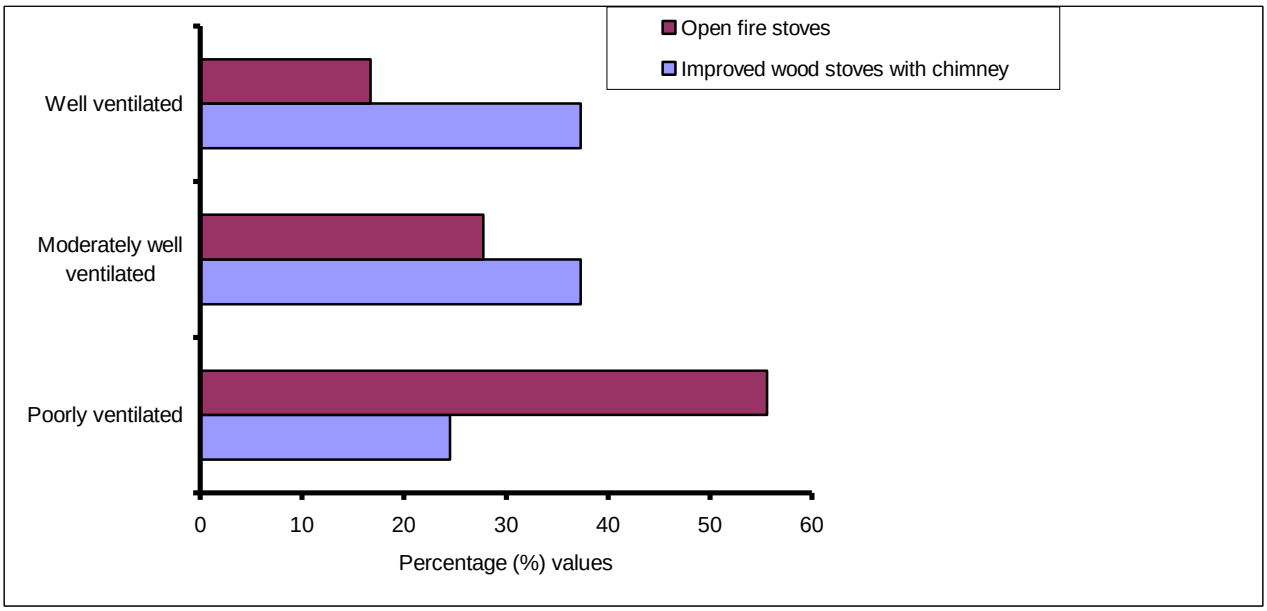

Figure 3: Shows the distribution of the percentages for the adequacy of ventilation

6.1.5 Kitchen Practices

In 60.0% of visited households, mothers were found to be responsible for cooking, while 21.8% and 9.2% were representing daughters and other members of the family respectively (sons, house-girls and house-boys). 69.0% of these cooking group categories cook three times a day, 27.6% twice a day and 3.4% of them cook once a day. Most of the visited households (90.8%) were using a specialized kitchen, 3.4% in a living room and the rest 5.8% had kitchens located within the bedroom.

While undertaking the study many other negative practices responsible for wasting the wood fuel were observed. For instance, while lighting the wood it was observed that in some cases the wood was left over an extended period of time and therefore being wasted. Good practice should be to extinguish the un-burnt wood and re-use it latter.

It was also revealed that 20 out of 68 assessed chimneys were performing poorly. Observed poor chimneys' performances could be associated with un-cleaned chimney; poor stove construction and chimney setting. The noted Okoa stoves with poor chimney performance were: HUD 03002, HUD 03003, HUD 03004, HUD 03005, HUD 03006, HWA 01026, HFO 04043, RSH 05003, RSH 05004, RMEN 1, RMEN 3, RKI 07001, RKI 07005, RMA 09003, RMA 09005, RMA 09006, RMA 09007, RSH 05010, RMJ 08001, and RMJ 08002.

6.1.6 Condition of the stoves

The condition of each stove was also rated under the help of constructed questionnaires and/or through observation. 37.3% of all assessed Okoa stoves were well constructed, 49.3% were moderately constructed and 13.4% found poorly constructed (Figure 4).

Figure 4: Examples of Okoa stoves with poorly constructed ash trays resulted into black stains (soot) on their front view.

Through observation, Okoa stoves coded HWA 01004, HUD 03002, HUD 03004, HUD 03006, RKI 07001, RKI07004, RMAH 06002 and RMJ08001 were poorly found constructed.

6.1.7 Households' respiratory disorders and other diseases related to IAP

The most significant of the respiratory disorders were chest tightening (16 cases) followed by post nasal drop (12 cases), coughing (11 cases), 4 wheezing complaints and lastly 3 cases of winter exacerbations. Other reported cases were on eye related infections which constituted 35 cases and 17 were complaints on headache. The eye infections disease was quite common but somehow quite significant among the aged people in the households. The study did not find any information on Asthma, Cataract and TB-related diseases within household members as per analyzed questionnaires.

However, it was not easy to conclude scientifically if these reported cases were directly caused by IAP or due to other factors like ageing, weather condition or inborn physical disabilities. Figure 6 shows the findings on health status (respiratory disorders and other reported cases) for household members using either Okoa stoves or open fire stoves.

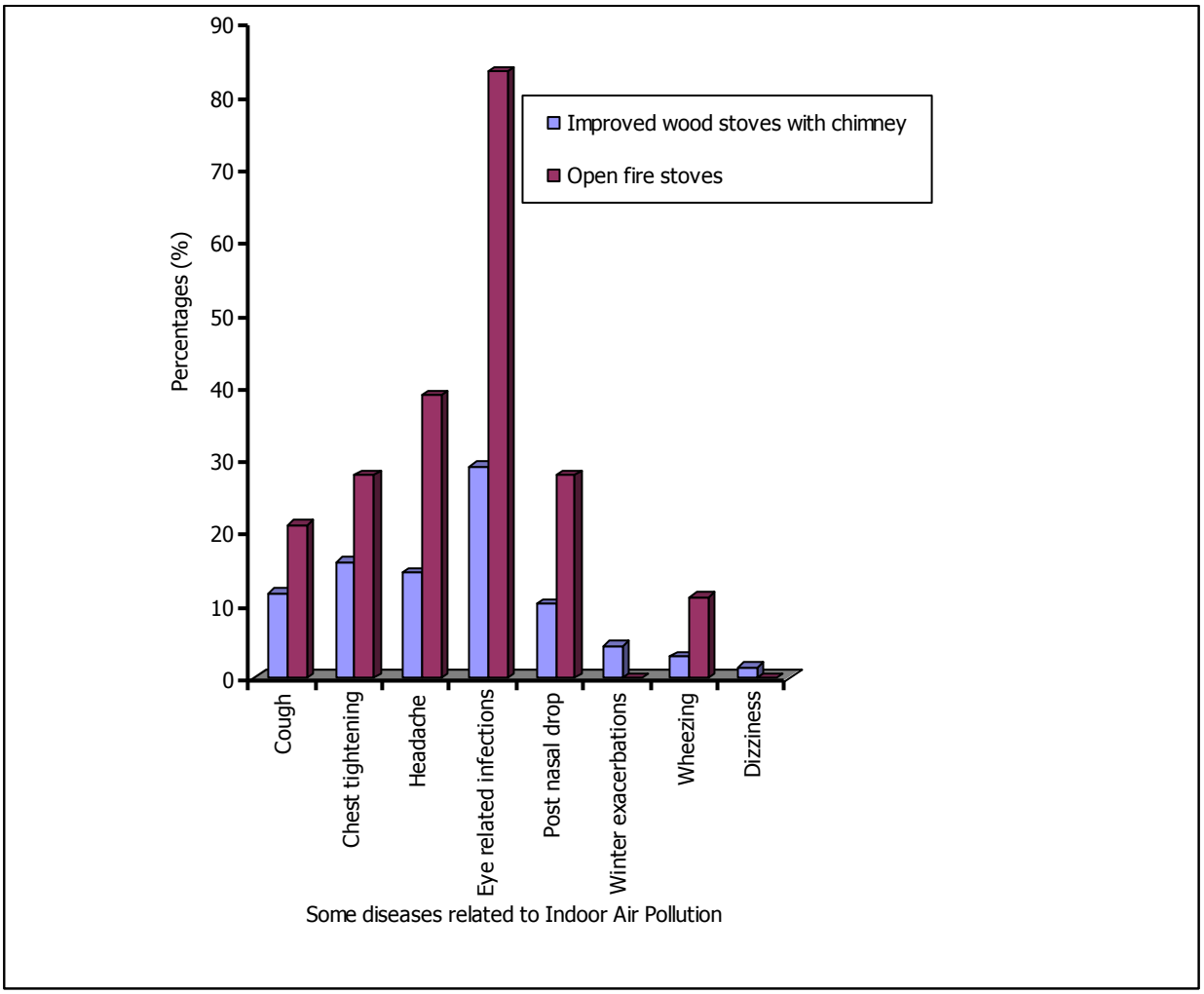

Figure 6: Health status

6.2 Indoor Air Pollution Measurements

The study has revealed the presence of air pollutants of carbon dioxide, carbon monoxide, nitrogen oxides, nitrogen monoxide and total suspended particulate matter that are associated with the cooking practices using wood stoves technologies.

Figure 2: Air contaminants measurement using Combustion Gas Analyzer and Microdust pro devices.

6.2.1 CO, CO_2, NO and NO_X Determination at Rombo District

Table 1 below shows the levels of measured parameters recorded from visited households using Okoa stoves at Rombo district.

Table 1: Gas emissions (CO, CO_2, NO and NO_X) measured from Okoa stoves at Rombo district

STOVE CODE	Concentration Values of Measured Pollutant Gases			
	CO in mg/m^3	CO2 in %	NO in mg/m^3	NOx in mg/m^3
RSH-05001	0.29	0.00	0.71	1.00
RSH-05002	14.33	0.03	0.00	0.00
RSH-05003	252.43	0.17	2.00	3.43
RSH-05004	80.15	0.03	0.43	0.76
RSH-05005	101.87	0.04	0.54	0.93
RSH-05006	115.10	0.04	0.61	1.03
RSH-05007	130.23	0.05	0.68	1.14
RSH-05008	35.29	0.07	0.00	0.00
RSH-05009	0.43	0.00	0.00	0.00
RSH-05010	2.43	0.00	0.00	0.00
RSH-05011	9.86	0.00	0.00	0.00
RME-1	168.00	0.06	0.77	1.33
RME-2	124.78	0.05	0.62	1.06

RME-3	129.71	0.05	0.64	1.09
RME-4	133.69	0.05	0.66	1.12
RKI-07001	2.29	0.00	0.29	0.29
RKI-07002	13.57	0.05	0.00	0.00
RKI-07003	0.86	0.00	1.14	1.71
RKI-07004	6.29	0.00	0.00	0.00
RKI-07005	4.43	0.10	0.00	0.00
RKI-07006	0.71	0.00	0.00	0.00
RKI-07007	7.14	0.00	0.00	0.00
RMAH-06001	57.43	0.11	1.14	1.86
RMAH-06002	5.57	0.00	1.14	1.86
RMAH-06003	80.86	0.00	2.00	3.43
RMA-09001	13.14	0.00	0.00	0.57
RMA-09002	12.86	0.00	1.14	2.00
RMA-09003	74.29	0.17	2.00	3.29
RMA-09004	11.14	0.00	0.57	1.00
RMA-09005	132.14	0.11	2.86	4.71
RMA-09006	24.14	0.00	0.00	0.00
RMA-09007	7.71	0.00	0.29	0.43
RMA-09008	16.00	0.01	0.14	0.14
RMJ-08001	61.86	0.11	0.00	0.43
RMJ-08002	73.29	0.07	0.71	1.00
OSHA PEL	**55**	**0.5**	**30**	**9**

While the highest concentration value of 252 mg/m^3 was obtained from Okoa stove with code number RSH 05003, the lowest value of 0.29 mg/m^3 was recorded from Okoa stove coded RSH 05001. The results in Table 1 shows that CO was the only parameter found having some concentration levels above acceptable OSHA standard limit of 55 mg/m^3 when Okoa stoves were tested at Rombo district. However, 43% of household using Okoa stoves were found with CO emmissions levels above acceptable OSHA standard limit of 55 mg/m^3 while the other 57% households were above that OSHA standard.

6.2.2 CO, CO_2, NO and NO_X Determination at Hai District

Table 2: Gas emissions (CO, CO_2, NO and NO_X) measured from Okoa stoves at Hai district.

STOVE CODE	Concentration Values of Pollutant Gases			
	CO in mg/m^3	CO2 in %	NO in mg/m^3	NOx in mg/m^3
HFO-04001	5.00	0.00	0.00	0.00
HFO-04002	0.14	0.00	0.00	0.00
HFO-04003	12.14	0.00	0.14	0.57
HFO-04004	8.24	0.00	0.08	0.20
HFO-04005	8.74	0.00	0.06	0.17
HFO-04043	0.29	0.00	0.00	0.29
HFO-04025	0.00	0.00	0.00	0.00
HFO-04020	16.57	0.00	0.14	0.14
HWA-01001	9.73	0.00	0.07	0.20
HWA-01002	8.89	0.00	0.08	0.23
HWA-01003	9.34	0.00	0.08	0.25

HWA-01004	9.04	0.00	0.07	0.21
HWA-01005	9.23	0.00	0.07	0.22
HWA-01010	1.86	0.00	0.00	0.00
HWA-01026	20.71	0.00	0.00	0.00
HUD-03001	9.30	0.00	0.08	0.23
HUD-03002	9.24	0.00	0.08	0.23
HUD-O3003	9.20	0.00	0.08	0.23
HUD-03004	9.18	0.00	0.08	0.22
HUD-03005	9.21	0.00	0.08	0.22
HUD-03006	9.24	0.00	0.08	0.22
HUD-03007	9.24	0.00	0.08	0.23
HNK-02001	9.22	0.00	0.08	0.22
HNK-02002	9.22	0.00	0.08	0.22
HNK-02003	9.23	0.00	0.08	0.22
HNR-00003	0.57	0.00	0.00	0.00
HNR-00005	0.43	0.00	0.57	1.00
HNR-00004	5.14	0.00	2.57	4.14
HNR-00007	4.86	0.00	0.57	1.00
HNS-06008	4.00	0.00	0.00	0.14
HNS-06005	0.57	0.01	0.00	0.00
OSHA PEL	**55**	**0.5**	**30**	**9**

Table 2 above shows that CO concentration measured in all the sampling households using Okoa stoves were between the range of 0.00 – 20.71 mg/m^3. This implies that the concentration of CO measured in all the sampling stations were below the OSHA PEL, which stipulates a figure of 55 mg/m^3. The highest concentration of 20.71 mg/m^3 was measured at Okoa stove coded HWA 01026 while the lowest concentration of 0.00 mg/m^3 was recorded at Okoa coded HFO 04025. Moreover, the concentrations for CO_2, NO and NO_X measured from all Okoa stoves in the six villages visited at Hai district were below OSHA PEL of 0.9%, 30 mg/m^3 and 9 mg/m^3 respectively. From the results it can be concluded that, the tested Okoa stoves at Hai district performed well. However, the Okoa stoves coded HWA 01004, HUD 03002, HUD 03004 and HUD 03006 (in section 6.1.6) were found to be poorly constructed although they performed well. This scenario might be associated with well ventilated kitchens and cleaned chimneys in which emitted air pollutants can easily be removed and/or diluted. It can also be attributed to the frequency of use as the more the Okoa stove is used the more likely it is for its chimney to be blocked by the deposited soot.

6.2.3 CO, CO_2, NO and NO_X Measured from Traditional Three Stones Fire Place at Hai and Rombo Districts

Table 3: Gas emissions (CO, CO_2, NO and NO_X) recorded from traditional three stones fire place at Hai and Rombo Districts.

STOVE CODE	Concentration Values of Measured Pollutant Gases			
	CO in mg/m^3	CO2 in %	NO in mg/m^3	NOx in mg/m^3
HTSFP1	32.29	0.00	0.29	0.57
HTSFP2	41.86	0.00	0.13	0.11
HTSFP3	25.57	0.00	0.32	0.16
HTSFP4	226.00	0.21	1.52	2.14
HTSFP5	114.29	0.08	0.14	0.29
HTSFP6	97.67	0.00	0.05	0.15
HTSFP7	9.96	0.00	0.09	0.26
HTSFP8	8.94	0.00	0.07	0.21
HTSFP9	109.29	0.04	0.09	0.23
HTSFP10	69.23	0.00	0.08	0.23
HTSFP11	9.23	0.00	0.07	0.22
RTSFP12	190.29	0.03	0.48	0.84
RTSFP13	148.79	0.06	0.68	1.16
RTSFP14	119.20	0.04	0.60	1.02
RTSFP15	108.86	0.09	1.00	1.43
RTSFP16	36.86	0.00	0.06	0.14
RTSFP17	52.43	0.01	0.14	0.29
RTSFP18	270.29	0.16	1.71	3.00
RTSFP19	17.40	0.00	0.03	0.13
OSHA PEL	**55**	**0.5**	**30**	**9**

The highest CO concentration values of 270.29 mg/m^3 and 226.00 mg/m^3 and lowest concentration values of 8.94 mg/m^3 and 17.40 mg/m^3 were recorded at Rombo and Hai districts respectively (Table 3). 53% of the examined households using traditional three stones fire place at Hai and Rombo districts were found with CO concentrations above OSHA PEL of 55 mg/m^3. The CO_2, NO and NO_X were found between the ranges of 0.00 mg/m^3 – 0.21 mg/m^3, 0.03 mg/m^3 – 1.71 mg/m^3 and 0.11 mg/m^3 - 3.00 mg/m^3 which falls below the OSHA PEL of 0.9%, 30 mg/m^3 and 9 mg/m^3 respectively.

Generally, the concentrations of the gaseous emissions (CO_2, NO, and NO_X) from both the Okoa stoves and traditional three stones fire place at Hai and Rombo districts were below the OSHA PEL of 0.9%, 30 mg/m^3 and 9 mg/m^3 respectively over whole measurement duration (Tables 1, 2 and 3). This implies that all the households using the two types of wood technologies are not exposed to extreme stove emmissions of CO_2, NO, and NO_X.

While CO concentration of more than 80% of the households using Okoa stoves complied with OSHA standard, CO values for 67% of households using traditional three stones fire

place were beyond the OSHA permissible exposure limit of 55 mg/m^3 over whole measurement duration (Appendix I). This implies that 80% of the households surveyed using improved wood stoves with chimney are not exposed to extreme stove emmissions compared to only 33% of those using traditional three stones fire place. From this result it can be concluded that Okoa stoves emitted less carbon monoxide in comparison to three stones fire place.

6.3 Measurements of Suspended Particulate Matter Emissions

Tables 3, 4 and 5 below show the concentrations of suspended particulate matter measured at Hai and Rombo districts community found using the two examined wood stoves technologies.

Table 3: Dust emissions summary measured from Okoa stoves at Hai district

S/NO.	STOVE CODE	Concentration in mg/m^3
1	HFO:04001	0.15
2	HFO:04002	0.13
3	HFO:04003	0.11
4	HFO:04004	0.10
5	HFO:04005	0.13
6	HWA:01001	0.10
7	HWA:01002	0.12
8	HWA:01003	0.24
9	HWA:01004	0.48
10	HWA:01005	0.28
11	HUD:03001	0.14
12	HUD:03002	0.35
13	HUD:03003	0.18
14	HUD:03004	0.23
15	HUD:03006	0.11
16	HUD:03007	0.19
17	HNK:02001	0.35
18	HNK:02002	0.10
19	HNK:02003	0.10
20	HNR:00003	0.27
21	HNR:00007	0.47
22	HWA:01010	0.14
23	HWA:01026	0.16
24	HFO:04043	0.18
25	HFO:04025	0.70
26	HFO:04020	0.33
27	HNS:06005	0.18
	WHO limits for 24 - hrs **OSHA PELfor 8 - hrs**	**0.15 -0.23** **15**

Table 4: Dust emissions summary measured from Okoa stoves at Rombo district

S/NO.	STOVE CODE	Concentration in mg/m^3
1	RSH:05002	0.10
2	RSH:05003	2.14
3	RSH:05004	0.35
4	RSH:05005	0.09
5	RSH:05006	0.31
6	RMEN1	0.18
7	RKI:07001	0.16
8	RKI:07007	1.26
9	RMAH:06001	0.26
10	RMAH:06002	0.50
11	RMAH:06003	0.60
12	RMA:09001	0.30
13	RMA:09002	0.53
14	RMA:09003	0.22
15	RMA:09004	0.20
16	RMA:09005	1.43
17	RMA:09007	0.19
18	RMA:09008	0.13
19	RSH:05008	0.57
20	RSH:05009	0.10
21	RSH:05010	0.16
22	RMA:05011	0.11
	WHO limits for 24 - hrs	**0.15 -0.23**
	OSHA PEL for8 - hrs	**15**

Table 5: Particulate matter summary measured from traditional three stone fire place

S/NO.	STOVE CODE	Concentration in mg/m^3
1	HTSWS2	1.12
2	HTSWS3	1.84
3	HTSWS5	1.78
4	HTSWS6	2.13
5	HTSWS7	0.32
6	HTSWS8	0.37
7	HTSWS9	1.48
8	HTSWS10	0.37
9	HTSWS11	1.17
10	RTSWS13	1.59
11	RTSWS14	0.51
12	RTSWS15	0.39
13	RTSWS17	0.77
14	RTSWS18	0.53
15	RTSWS19	0.28
	WHO limits for 24 - hrs	**0.15 -0.23**
	OSHA PEL for 8 hrs	**15**

Suspended particulate matter was found to be the most significant air pollutant in all households using traditional three stones fire place stoves and to some extent for Okoa users at Hai and Rombo districts. The highest concentrations of suspended particulate matter of 0.7 mg/m^3 and 2.14 mg/m^3 and lowest values of 0.1 mg/m^3 and 0.09 mg/m^3 were recorded from Okoa stoves at Hai and Rombo districts respectively. However, 33.3% and 50% of Okoa stoves tested at Hai and Rombo districts respectively were found to emit particulate matter concentrations above the WHO limit of 0.15 – 0.23 mg/m^3 (Tables 4, 5 and 6). The particulate matter concentrations measured from all households using three stones fire place at the two visited districts were between the range of 0.28 – 2.13 mg/m^3 which falls above WHO limits stipulated to 0.15 – 0.23 mg/m^3 range for 24 hours. Generally these particulate matter results suggest that, there is the need for improvement on the control of suspended particulate matter emitted from both tested wood stoves technologies. For example an improvement in the stove operation and proper construction of stoves combustion chambers, air channels and wood trays together with good housekeeping can improve the efficiency of dust collection and reduce dust generation within the kitchen/indoor environment.

6.4 Users' Perceptions on the Improved Wood Stoves with Chimney

The users were able to differentiate between Okoa stoves and traditional three stone stoves in terms of wood consumption as Okoa stoves consumed less wood than open fire place stoves. Other household members mentioned discomfort caused by the use of three stones fire place stove as it tend to increase the temperature of a cooking place. The temperature increment might be caused by high radiations from uncovered combustion chamber between three stones/blocks. Negative perceptions of Okoa stoves were associated with its use as it can not be used to smoke meat, dry stocked wood, and warm kitchen area and ripen banana. Also, users protested against the project's cost sharing policy as installation cost of Okoa stoves is still higher and cannot be afforded by the low income group.

On the other hand, local community at Hai and Rombo districts in Kilimanjaro region still have a question mark over their ability to cope without using open fire place stoves, the technology adopted from their ancestors. Therefore, a challenge for TaTEDO is to change peoples' mind in order to have great affection for the introduced Okoa stoves by serving

their demands. People's demands can be attained with Okoa stoves including warming their bodies/kitchen during cold seasons, drying their stocked wood (un-dried wood stocks), to smoke and preserve meat (ndafu) and ripen banana.

7.0 LESSON LEARNED

- Wood smokes emitted from the kitchens separated from main house were observed entering the living houses. This was due to differences in height between chimney length and living room. Smoke from short set chimneys was driven by wind towards the main house. Therefore, individuals who were inside the living house during the cooking activity also face air pollutants exposure emitted from the cooking place.
- Most of the households using Okoa stoves were lacking users' education. While some were found not inserting designed ash trays, some were not even aware whether the stove's chimney should (need to) be cleaned.
- Distortion of information during transfer of knowledge. This situation was noted when trained Okoa stoves technicians become TOT to train others and qualify them as new technicians to have the same duty of constructing Okoa stoves. As this chain expanded, will worsen the performances and status of Okoa stoves. Sometimes, some Okoa stoves which were constructed by trained TaTEDO technicians were used before even being pre-assessed by concerned TaTEDO field staff.
- Cost implication for Okoa stoves which varies from TShs. 130,000/- to 360,000/- depending to the types of Okoa stove (i.e., Okoa number1, 2 or 3) to be constructed. Some people especially in Rombo district were interested to have Okoa stoves but due to their financial constraints could not afford to meet Okoa's construction cost.
- It seems like there is also a culture barrier on the use of improved wood stoves with chimney.
- Most of the used improved wood stoves with chimney were found with cracks.
- Most of households at Hai district were found not using their improved wood Okoa stoves regularly compared to Rombo district users.

8.0 CONCLUSION

The findings of this study have revealed the presence of complex mixture of particulate and gaseous emissions that were associated with the cooking practice using the tested wood stove technologies. More than 80% of the measured Okoa stoves were found with CO concentration below OSHA permissible exposure limit of 55 mg/m^3 whereas, the CO values measured from 67% traditional three stones fire place were beyond the stipulated OSHA standard over whole measurement duration. This meaning that more than 80% of the Okoa stoves users' were not exposed to extreme CO emmissions compared to those 33% using three stones fire place. From such a result it can be concluded that Okoa stoves emitted less carbon monoxide in comparison to three stones fire place. Likewise, all measured Okoa stoves and traditional three stones fire place at Hai and Rombo districts were having CO_2, NO, and NO_X concentrations below the OSHA PEL of 0.9%, 30 mg/m^3 and 9 mg/m^3 respectively over whole measurement duration. This implies that CO_2, NO, and NO_X values emitted from two types of wood stove technologies at Hai and Rombo districts community were within stipulated OSHA standards and therefore safe for human health.

On the other hand, suspended particulate matter concentrations were found to be the most significant air pollutant in all households using traditional three stones fire place stoves and Okoa users to some extent at Hai and Rombo districts. The highest concentrations of suspended particulate matter of 0.7 mg/m^3 and 2.14 mg/m^3 were recorded from Okoa stoves at Hai and Rombo districts respectively. However, 33.3% and 50% of Okoa stoves tested at Hai and Rombo districts respectively were found to emit particulate matter concentrations above the WHO limit of 0.15 – 0.23 mg/m^3. All particulate matter concentrations measured from three stones fire place at the two visited districts were between the range of 0.28 – 2.13 mg/m^3 which falls above WHO limits stipulated of 0.15 – 0.23 mg/m^3. This suggests that Okoa stoves were producing lower particulate matter concentrations than three stones fire place.

Generally, these indoor air contaminants were found to have negative effect to operators who in most cases were mothers and daughters. Therefore there is the need for improvement on the control of suspended particulate matter and emitted IAP from both tested wood stoves technologies.

Proper constructed and utilization of Okoa stove provides an important aspect in minimizing IAP and particulate matter. Based on questionnaires analysis it was revealed that, while some Okoa stoves were poorly constructed, some were found placed in the poorly ventilated kitchens. However, selection of appropriate pot sizes in relation to the size of pot guard(s), the use of dried wood and removal of accumulated ashes under wood trays were not regularly followed. Also culture of cleaning chimney was lacking among most of the sampled households.

These named factors could attribute to the poor performances of the Okoa stoves. As the improvement of Okoa stove operation and proper construction of stoves' combustion chambers, wood trays, air channels together with good housekeeping could improve the efficiency of dust collection and reduce dust and IAP generation within the kitchen/indoor environment.

9.0 RECOMMENDATIONS

- The use of Okoa stoves (viewed as a pilot project) should be extended to other areas so as to extend the benefits gained in Hai and Rombo districts. It seems still there are untapped markets/demands within the two piloted districts and in the other four districts left in Kilimanjaro region.
- Presence of black stain (soot) on the front view(s) of Okoa stoves (wood chambers' doors) and high indoor smoke are the indicative factors of poorly designed feed-wood hoppers/trays. TaTEDO should redesign their feed-wood hopper/trays to be at an angle (a slanted feed-wood hopper) and that will enable wood to move in the combustion chamber automatically (itself) by sliding slightly after it fore part being burnt/consumed.
- Reducers of different nature should be designed to support the users' pot/pans of different sizes while maintaining the same height between pot/pan base and combustion chamber. Currently most of the visited Okoa users were able to use only two pot/pans as per the size of fixed two pot guards.
- No efficiency tests are known to us that had been conducted on these stove models. Therefore, essentiality of such kind of missing data calls for another research in order to document the lacking findings.
- Before the improved wood stoves with chimney can fully be utilized to substitute open fire place stoves, further comprehensive study should be employed to

determine concentration levels of heavy metals (e.g., Iron, Lead, Cadmium, Mercury, Arsenic, Nikel, Zinc, Cobalt, Aluminium, Copper, Manganise and Chromium); sulphur dioxide and hydrocarbons. Also particulate matter characterization (ranging from PM_1, respire-able, $PM_{2.5}$ to PM_{10}); energy efficiency and stove performance test should be employed to clearly define the status of Okoa stoves.

- Since eye infections can be also associated with light intensity (illuminance); another study should be designed to focus on illuminance determination. Likewise, heat levels associated with the use of Okoa stoves that surround the coking environment should also be examined.
- Since emissions from the wood cooking stoves have negative health impact to operators; a better chimneys design and ex-filtration of toxic gases should be introduced. All noted Okoa stoves with poor performances chimneys (section 6.5) or poorly maintained (section 6.6) should either be renovated or dismantled and reconstructed in order to attain performance criteria. Also All Okoa stoves with air pollutants or particulate matter concentrations above OSHA PEL or WHO recommended standards, should be dismantled and reconstructed.
- Poorly ventilated cooking environment is highly associated with increased IAP, therefore TaTEDO management should advice their trained technicians not to construct Okoa stoves in poorly ventilated kitchens. For those Okoa stoves constructed in poorly ventilated kitchen should either be shifted to the well ventilated areas or their kitchen ventilation should be improved.
- Due to current economical crisis, the objectives of Okoa stoves project can not be attained with the cost sharing policy of Okoa stove project. Therefore, there is a need for TaTEDO to provide full assistance to low income group on need who can not afford to have such services in place.
- Information on effects of emission on human should be retrieved from the users and Health Care Centers (hospitals and/or dispensary) attended by the tested Okoa stoves' users.
- Despite the low concentration of pollutants determined to some households, the cook should avoid the following for her/his safety:
  (a) To stay at the wind direction as he/she can inhale a large amount of carbon monoxide (which is a silent killer).

(b) To stay for a long time closer to the stoves with burning wood as his/her body may be sensitive to minute amounts of non-toxic particulate that may also be released by the burning wood.

- Lastly, efforts must be made towards community education on kitchen/stoves management in order to make any improvements on this constructive developed idea. Until such target can be made, Okoa stoves may prove a useful substitute of open fire place stove that use few wood materials with a good indoor air quality status.

10.0 REFERENCES

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11.0 APPENDIX

Appendix I: Indoor Air Polluted gases recorded from Okoa and Open fire place stoves inHai and Robo districts.

STOVE CODES	CO in mg/m^3	CO_2 in %	NO in mg/m^3	NOx in mg/m^3
HFO-04001	5.00	0.00	0.00	0.00
HFO-04002	0.14	0.00	0.00	0.00
HFO-04003	12.14	0.00	0.14	0.57
HFO-04004	8.24	0.00	0.08	0.20
HFO-04005	8.74	0.00	0.06	0.17
HFO-04043	0.29	0.00	0.00	0.29
HFO-04025	0.00	0.00	0.00	0.00
HFO-04020	16.57	0.00	0.14	0.14
HWA-01001	9.73	0.00	0.07	0.20
HWA-01002	8.89	0.00	0.08	0.23
HWA-01003	9.34	0.00	0.08	0.25
HWA-01004	9.04	0.00	0.07	0.21
HWA-01005	9.23	0.00	0.07	0.22
HWA-01010	1.86	0.00	0.00	0.00
HWA-01026	20.71	0.00	0.00	0.29
HUD-03001	9.30	0.00	0.08	0.43
HUD-03002	9.24	0.00	0.07	0.36
HUD-O3003	9.20	0.00	0.05	0.23
HUD-03004	9.18	0.00	0.06	0.22
HUD-03005	9.21	0.00	0.08	0.12
HUD-03006	9.24	0.00	0.09	0.62
HUD-03007	9.24	0.00	0.04	0.23
HNK-02001	9.22	0.00	0.09	0.42
HNK-02002	9.22	0.00	0.06	0.22
HNK-02003	9.23	0.00	0.08	0.12
HNR-00003	2.57	0.00	0.00	0.00
HNR-00005	2.43	0.00	0.57	1.00
HNR-00004	5.14	0.00	0.55	1.14
HNR-00007	4.86	0.00	0.51	1.00
HNS-06008	4.00	0.00	0.00	0.14
HNS-06010	3.71	0.00	0.00	0.10
HNS-06005	2.57	0.00	0.00	0.17
HOFS1	32.29	0.00	0.29	0.57
HOFS2	41.86	0.00	0.13	0.11
HOFS3	25.57	0.00	0.32	0.16
HOFS4	226.00	0.21	1.52	2.14
HOFS5	114.29	0.08	0.14	0.29
HOFS6	97.67	0.00	0.05	0.15
HOFS7	9.96	0.00	0.09	0.26
HOFS8	8.94	0.00	0.07	0.21
HOFS9	109.29	0.04	0.09	0.23
HOFS10	69.23	0.00	0.08	0.23
HOFS11	9.23	0.00	0.07	0.22
RSH-05001	0.29	0.00	0.71	1.00
RSH-05002	14.33	0.03	0.00	0.00
RSH-05003	252.43	0.17	2.00	3.43
RSH-05004	80.15	0.03	0.43	0.76
RSH-05005	101.87	0.04	0.54	0.93
RSH-05006	115.10	0.04	0.61	1.03
RSH-05007	130.23	0.05	0.68	1.14
RSH-05008	35.29	0.07	0.00	0.00
RSH-05009	0.43	0.00	0.00	0.00
RSH-05010	2.43	0.00	0.00	0.00
RSH-05011	9.86	0.00	0.00	0.00
RME-1	168.00	0.06	0.77	1.33
RME-2	124.78	0.05	0.62	1.06
RME-3	129.71	0.05	0.64	1.09
RME-4	133.69	0.05	0.66	1.12

RKI-07001	2.29	0.00	0.29	0.29
RKI-07002	13.57	0.05	0.00	0.00
RKI-07003	0.86	0.00	1.14	1.71
RKI-07004	6.29	0.00	0.00	0.00
RKI-07005	4.43	0.10	0.00	0.00
RKI-07006	0.71	0.00	0.00	0.00
RKI-07007	7.14	0.00	0.00	0.00
RMAH-06001	57.43	0.11	1.14	1.86
RMAH-06002	5.57	0.00	1.14	1.86
RMAH-06003	80.86	0.00	2.00	3.43
RMA-09001	13.14	0.00	0.00	0.57
RMA-09002	12.86	0.00	1.14	2.00
RMA-09003	74.29	0.17	2.00	3.29
RMA-09004	11.14	0.00	0.57	1.00
RMA-09005	132.14	0.11	2.86	4.71
RMA-09006	24.14	0.00	0.00	0.00
RMA-09007	7.71	0.00	0.29	0.43
RMA-09008	16.00	0.01	0.14	0.14
RMJ-08001	61.86	0.11	0.00	0.43
RMJ-08002	73.29	0.07	0.71	1.00
ROFS12	190.29	0.03	0.48	0.84
ROFS13	148.79	0.06	0.68	1.16
ROFS14	119.20	0.04	0.60	1.02
ROFS15	108.86	0.09	1.00	1.43
ROFS16	36.86	0.00	0.06	0.14
ROFS17	52.43	0.01	0.14	0.29
ROFS18	270.29	0.16	1.71	3.00
ROFS19	17.40	0.00	0.03	0.13
OSHA PEL	**55**	**0.5**	**30**	**9**

Appendix II: Wood stove technologies used by Household members at Hai and Rombo Districts

Figures a-h below illustrate some of wood technologies found used by community members in Hai and Rombo districts.

Fugure a: Shows JIKO SANIFU (left) and traditional three stones fire place (right).

Figure b: Showing two pictures of Okoa number 1 stoves with two pot guards each.

Figure c: Shows two pictures of Okoa number 2 stoves each having two pot guards and one water boiler pot with tap used in Hai and Rombo districts.

Figure d: Okoa stove number 3 having two pot guards, oven and water boiler pot with water tap.

Figure e: Two in one Okoa number 1 stove, with four pot guards mostly found used in the Institutions like schools.

Figure f: Modified Okoa number 1 stove with metal pipe which direct hot/warm water to the bathroom (shower) or tap.

Fugure g: Shows modified Okoa number 2 stove having three pot guards with a capacity of boiling water in a tank of 120 litters placed outside the kitchen.

Fugure h: Shows improved wood stove with chimney (presented by 3 pictures above) having four hot plates at the top for cooking, wood storage chamber, two bakery units and a water boiler chamber with a capacity of 20 litters.