Epidemiological survey of populations exposed to heavy metals and trace elements from Mining activities in Uganda. A case study of Kilembe copper mine catchment

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Introduction

- The mining and processing of copper from1956 to 1982 left a legacy of metalliferous material (tailings etc.) dumped mainly within a mountain river valley
- Toxic metals eroding into agricultural soils and public water sources
- Mine dust also getting into residential and public places, exposing local people to contaminated dust

Mine tailing erosion

Mine tailing 2016

Mine tailing 2020

Mine contaminated waters

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Inhabitation of mine contaminated sites

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Effects of flooding on crop fields and water

Physical exposure to PTEs at glance

Exposure pathways: Ingestion (food +drinking water), Inhalation (dust), Dermal contact (dust and bathing water)

The problem

- Past copper mining and processing activities left behind potentially toxic elements in mine wastes
- Past studies e.g Mwesigye et al (2016) found Kilembe soils to be contaminated with large quantities of Cu, Co, Ni, Zn, Mn, Pb and As, with some exceeding agricultural thresholds
- Mwesigye and Tumwebaze (2017) found public water sources and domestic water supplies in Kilembe to containing Fe, Al, Mn, Pb, As, Cu and Co in larger quantities, with some exceeding recommended thresholds
- Mwesigye et; al (2016) Found that house dusts in Kilembe mine area contained Cu, Co, Ni, Fe, Al, As and Pb which were exceeding thresholds of residential sites in some cases

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Problem contd.

- Mwesigye et. al (2019) Found that all food crops grown in Kilembe mine valley contained large quantities of Cu, Co, Zn, Mn, Pb, As, etc…
- Mwesigye et. al (2016) found that toe nails of Kilembe residents contained larger quantities of Cu, Co, Pb, As, Al and Fe, with children more affected than adults---confirming exposures
- Pb and As are largely carcinogenic and exposure could lead to cancer
- Fe, Al, Cu, Mn, Co, Ni, sulphides ingestion could cause gastro-intestinal complications

Problem contd

- Inhalation of dust containing Fe, Al, Cu, Mn, Co, Ni, sulphides, etc could cause respiratory complications in human beings
- Children are more affected by exposure than adults because of small body weight
- This particular study was therefore conducted to assess if the population exposures in Kilembe mine area through foods, water and house dusts are causing the diseases of concern

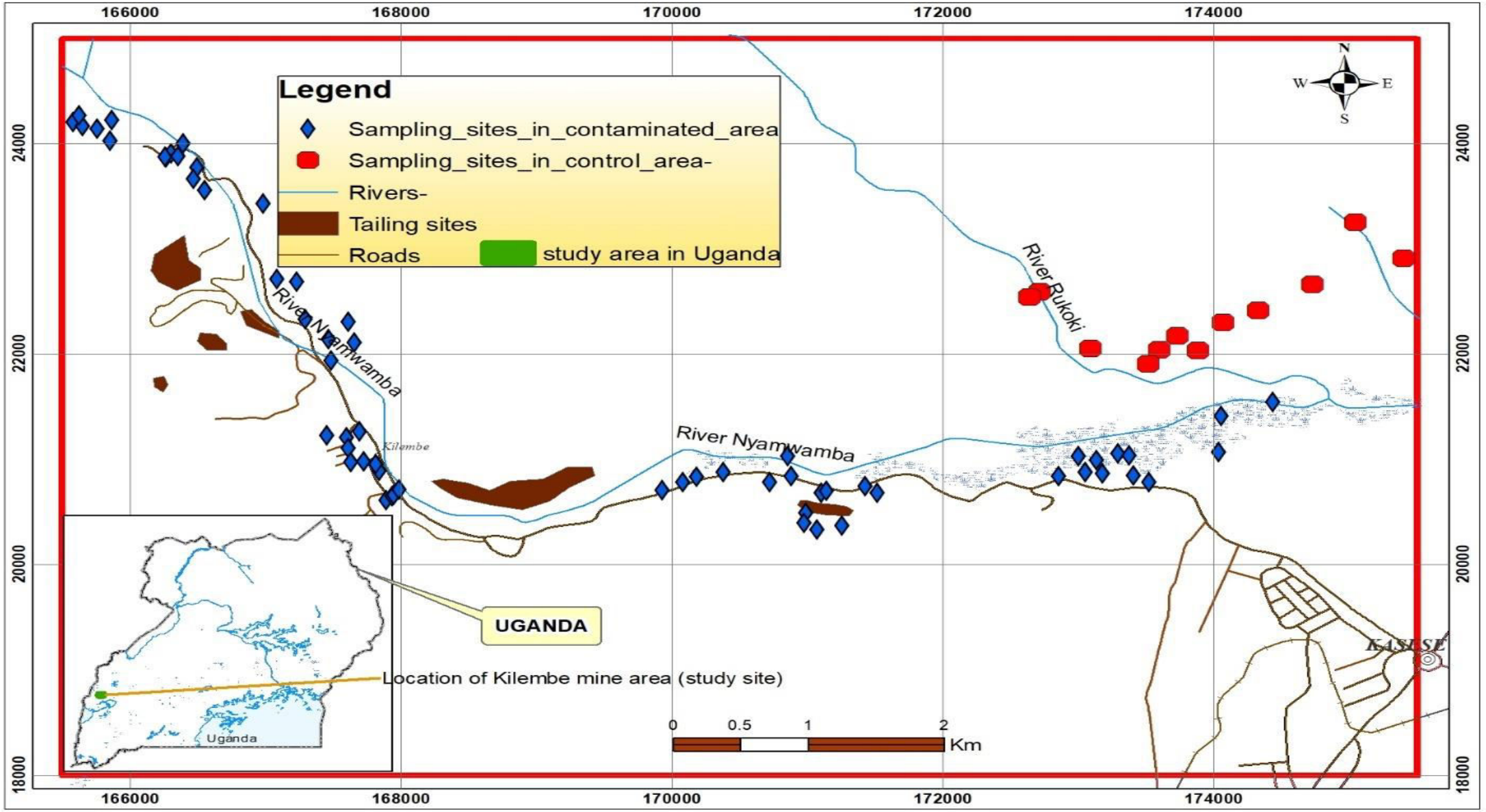
Specific objectives

- Investigate the occurrence of diseases among residents of Kilembe mine catchment which can be associated with mine and mine waste exposure
- Assess the relationship between occupational and residential exposures to heavy metals and trace elements from Kilembe copper mine to incidences of cancer, gastrointestinal diseases and ulcers
- Evaluate the roles of gender, age and occupation in exposing Kilembe residents to Kilembe mine wastes
- Investigate the level of public awareness of the dangers associated with exposure to heavy metals and trace elements from Kilembe mine

Methods

- Case control study involving exposed and non-exposed group (control)
- Health survey conducted in Kilembe mine catchment involving potentially exposed group with investigations on prevalence of respiratory, gastro-intestinal and cancer among households
- Data collected using a questionnaire
- Key informant interviews also conducted involving personnel from MEMD, MWE, NEMA, Kasese district local government

Sketch map of study area



Data collection continued

- Patient records obtained from Kilembe mines hospital and Kasese Municipality Health Centre III, the health facilities receiving patients from Kilembe mine area to profile common diseases registered
- Samples of domestic water, public water sources collected from Kilembe area and Rukoki (control)
- Samples of vegetables collected from Kilembe households with registered cases of cancer, respiratory and gastro-intestinal diseases as well as Rukoki (control)
- Samples of house dusts collected from Kilembe households with registered cases of cancer, respiratory and gastro-intestinal diseases as well as Rukoki (control)
- Toe nails (biomarkers of exposure) collected from Kilembe mine patients with diagonised cases of cancer, gastro-intestinal and respiratory diseas as well as Rukoki (control) group

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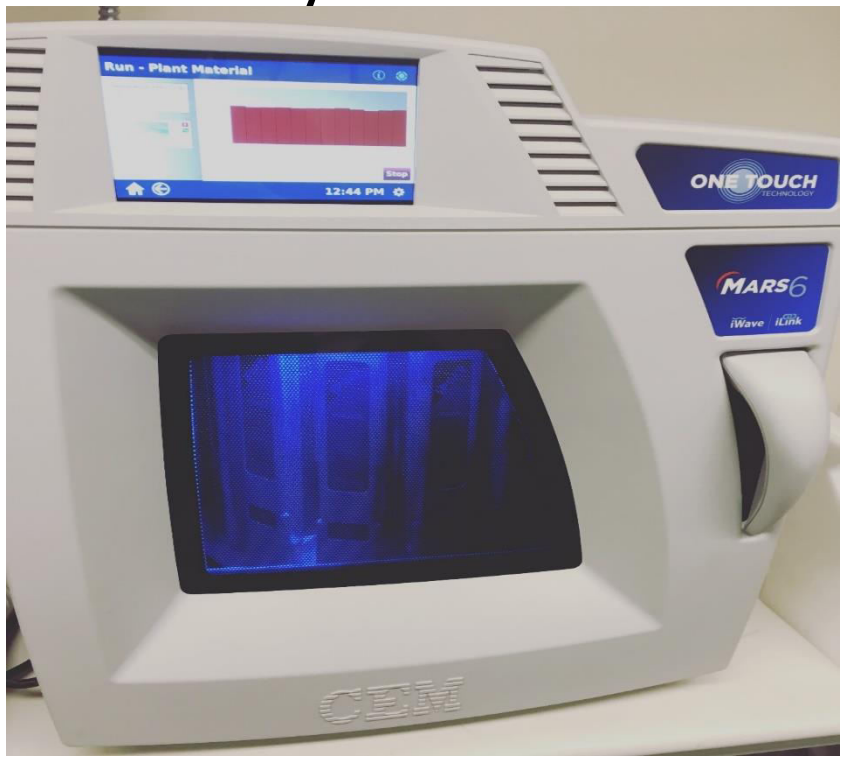
- Samples of water, vegetables, toe nails prepared following standard protocols and tested for presence of potentially toxic elements
- Tests conducted using Induced Coupled Plasma –Mass Spectrometer (ICP-MS), from the school of Biosciences, Nottingham University-UK



Microwave sample digestions

ICP-MS multi-elemental analytical system

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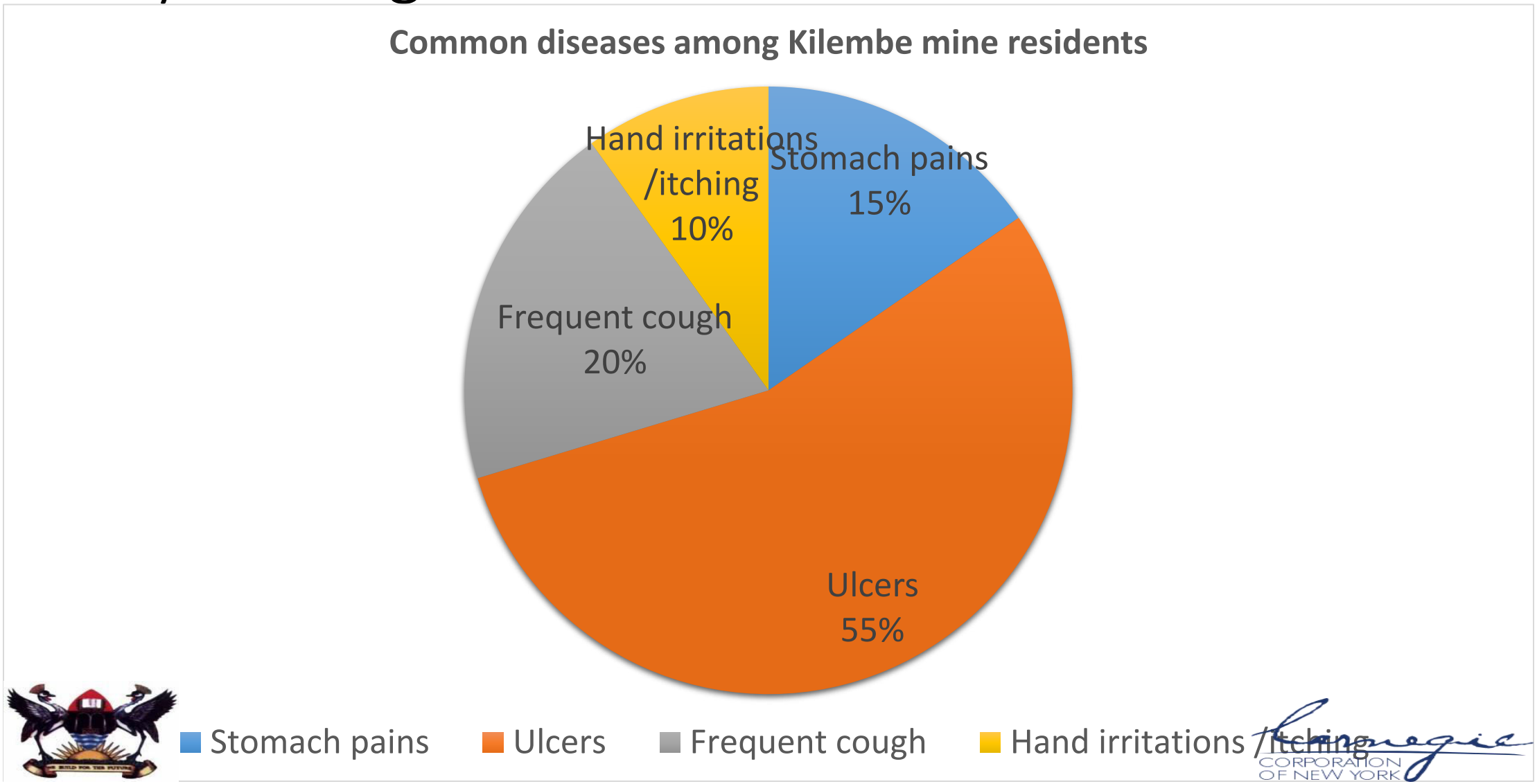
Quality controls and ethical considerations

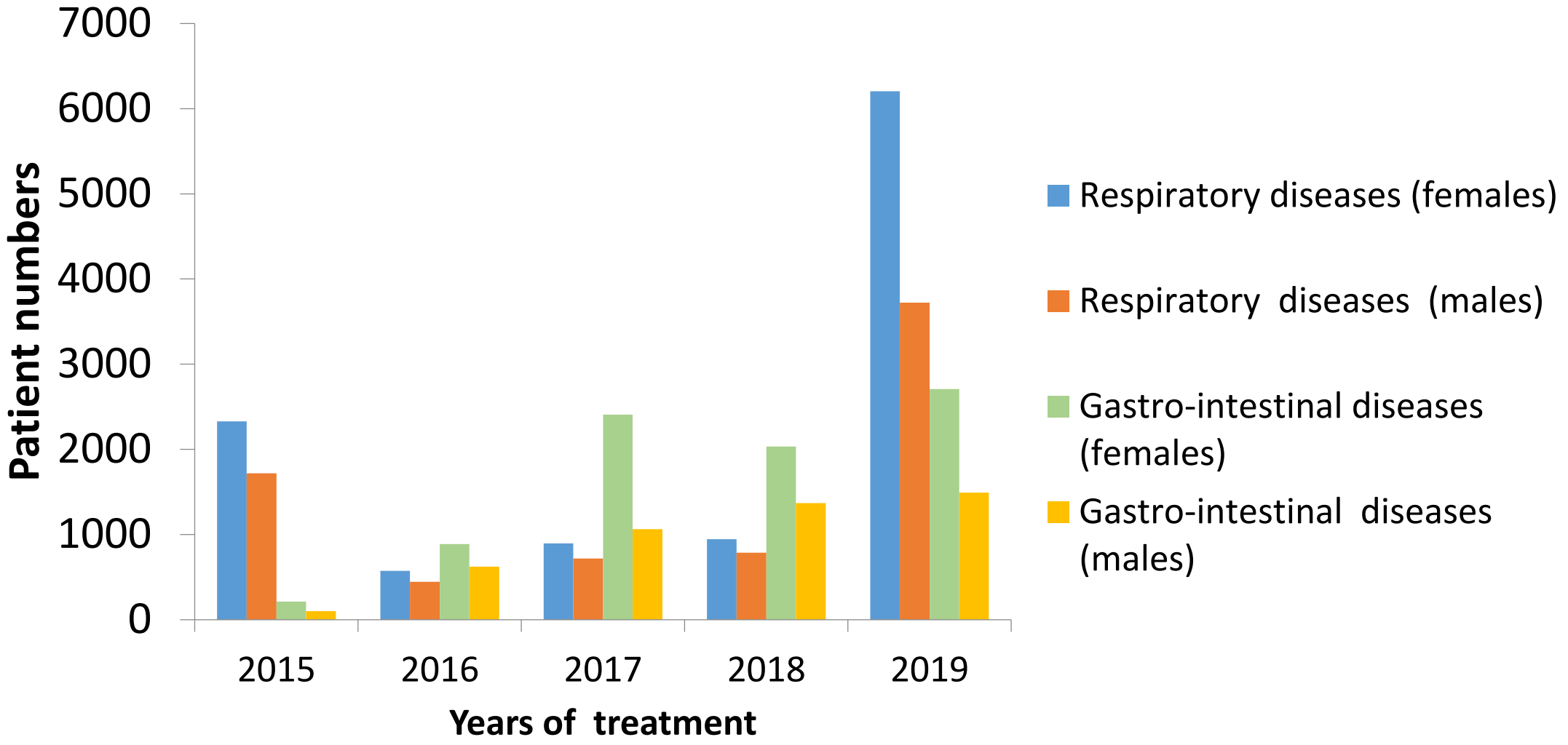
- Survey tools pretested before use in the field
- Study protocol approved by the school of Public health, MAK
- Samples of water, vegetables, house dusts prepared and tested in duplicates
- Reagents used were analytical and trace analytical grade, supplied by Fischer Scientific, UK
- Informed consent sought for respondents as well as volunteers for

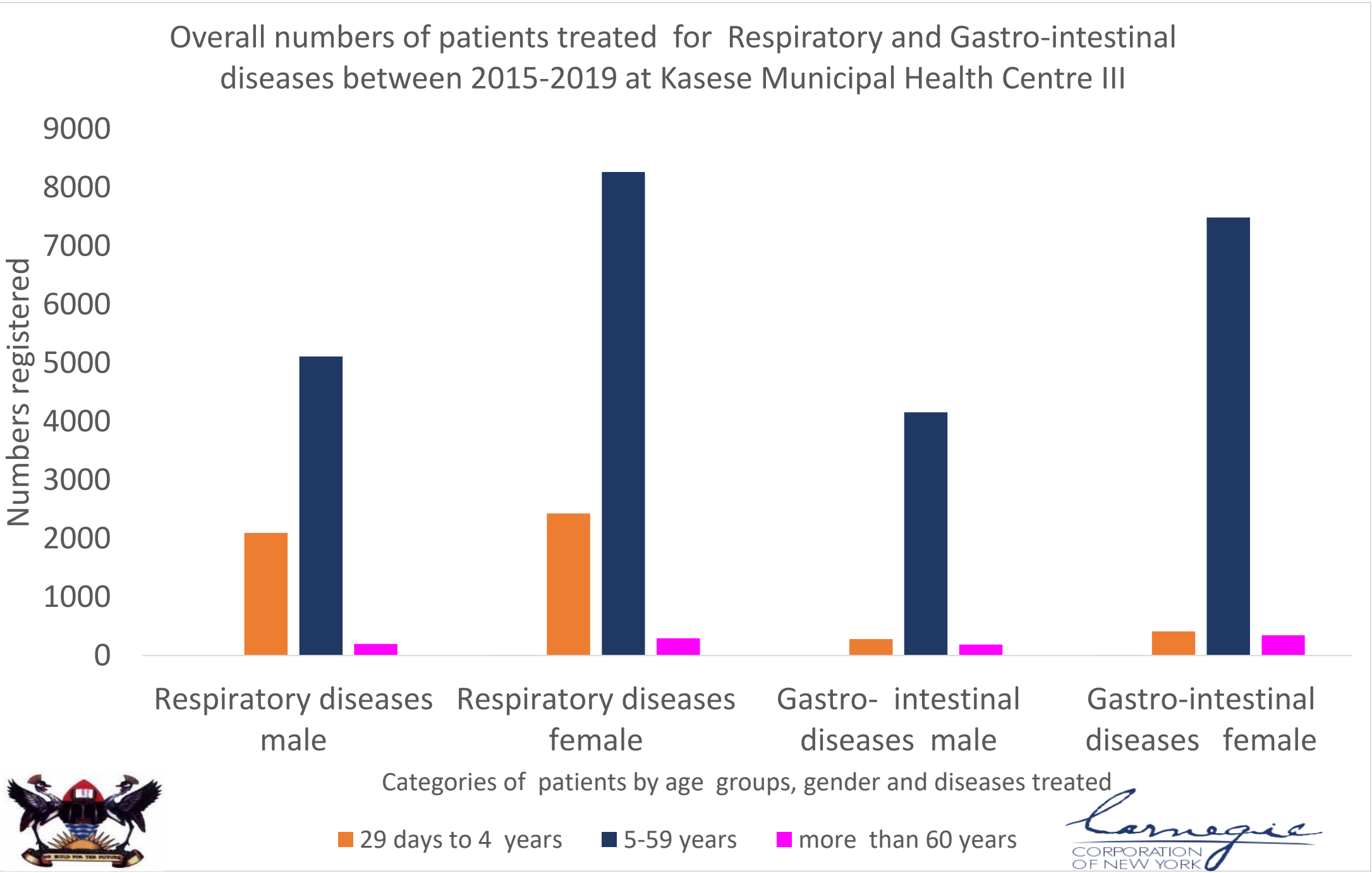
Toe nails collections

Study findings



Trend of patients treated for respiratory and gastro-intestinal diseases between 2015-2019 at Kasese Municipality Health Centre III




Overall numbers of patients treated for Respiratory and Gastro-intestinal diseases between 2015-2019 at Kasese Municipal Health Centre III
Numbers registered
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Respiratory diseases male
Respiratory diseases female
Gastro- intestinal diseases male
Gastro-intestinal diseases female
Categories of patients by age groups, gender and diseases treated
29 days to 4 years
5-59 years
more than 60 years
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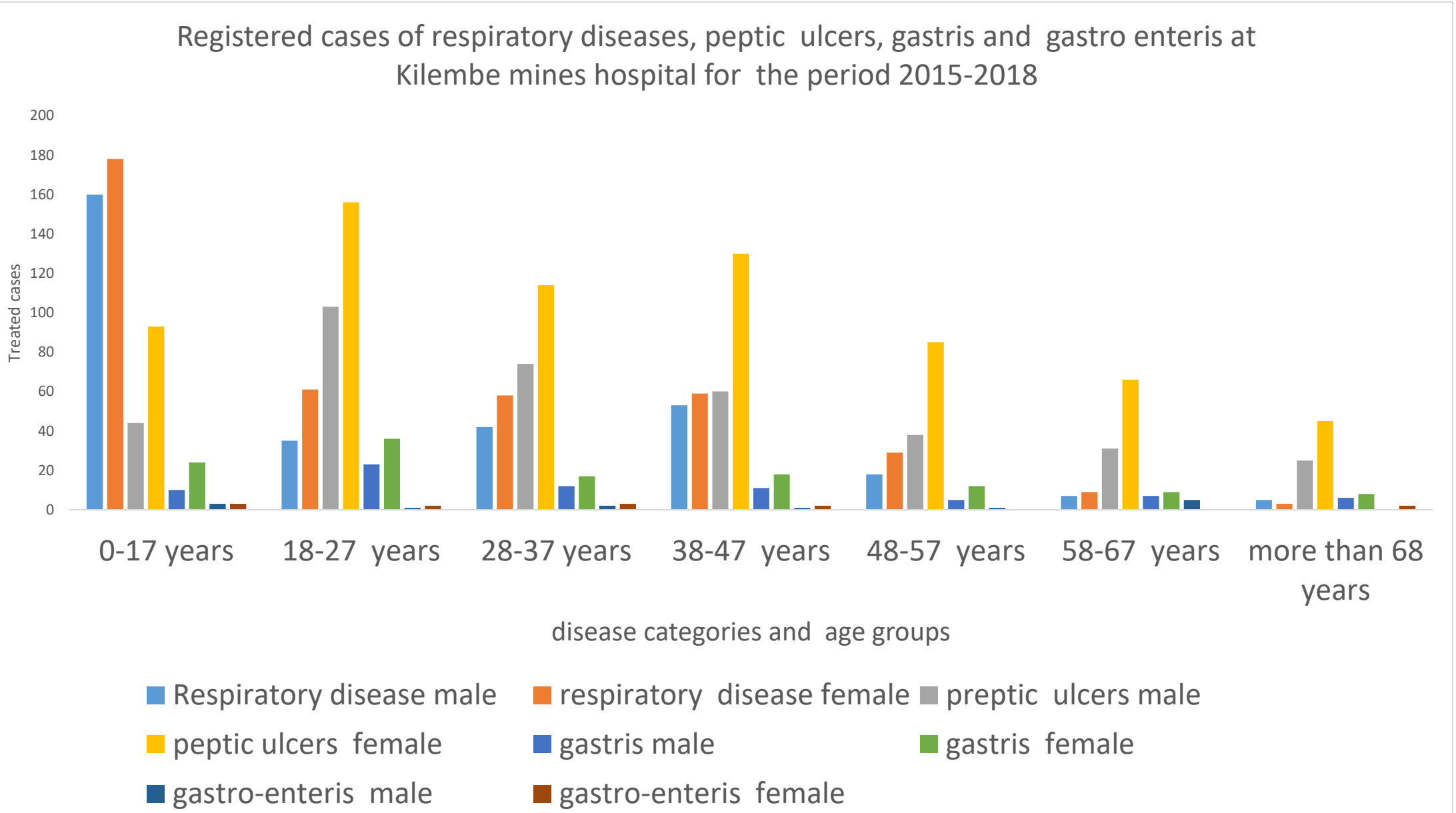

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Contamination of house dusts

Dust source	Kilembe catchment Dust (N=43)		Control dust (N=18)		Residential dust thresholds (NSE).
Element	Range	Mean ± SD	Range	Mean ± SD	
Al	4118 - 18411	7083 ± 2546	3194 - 8641	6240 ± 2451	
Cr	15.53 - 86.49	35.20 ± 17.14	24.65 - 83.69	44.62 ± 19.58	
Mn	219.8 - 875.2	438.6 ± 180.7	253.6 - 1097.3	509.1 ± 264.2	
Fe	14798 - 4198	23009 ± 6669	12884 - 39103	23114 ± 8643	
Co*	7.46 - 188.29	25.2 ± 30.69	4.64 - 18.83	11.62 ± 4.60	22
Ni	9.65 - 69.5	24.66 ± 13.6	5.12 - 30.68	14.87 ± 9.18	130
Cu*	13.3 - 3578.9	235.0 ± 576.2	3.77 - 54.3	18.23 ± 16.27	1100
Zn	24.6 - 506.4	115.3 ± 109.0	9.24 - 90.5	44.5 ± 28.8	5600
As	0.52 - 19.08	3.09 ± 3.99	0.65 - 2.36	1.429 ± 0.72	31
Cd	0.02 - 0.47	0.11 ± 0.09	0.02 - 0.1	0.05 ± 0.03	14
Pb*	4.58 - 402.02	20.61 ± 59.89	4.54 - 11.31	8.4 ± 2.33	140

For all samples, PTE in dust from Kilembe mine area were significantly higher than controls ($p<0.05$)

Trace elements in vegetables

Amaranthus	Kilembe catchment Amaranthus, N = 39		Control samples N = 19		Vegetable thresholds
Element	Range	Mean ± SD	Range	Mean ± SD	
Al	128.3 - 671.8	292.7 ± 137.6	184.5 - 672.2	352.6 ± 146.9	
Cr	0.19 - 1.65	0.69 ± 0.36	0.24 - 1.56	0.57 ± 0.38	
Mn	49.0 - 396.06	105.06 ± 57.35	93.04 - 156.85	116.91 ± 23.49	
Fe	263.1 - 1110.6	503.9 ± 194.9	332.1 - 962.6	504.5 ± 184.9	
Co	0.36 - 18.23	2.26 ± 3.5	0.35 - 0.99	0.58 ± 0.21	50a
Ni	0.48 - 3.82	1.32 ± 0.76	0.63 - 1.9	0.98 ± 0.37	66.9a
Cu*	7.96 - 55.93	15.26 ± 8.34	5.97 - 12.42	8.88 ± 1.94	20b
Zn*	59.5 - 489.6	140.7 ± 85.9	52.0 - 90.67	69.81 ± 12.41	99.4a
As	0.02 - 1.44	0.17 ± 0.26	0.02 - 0.12	0.05 ± 0.03	
Cd*	0.04 - 0.56	0.16 ± 0.11	0.06 - 0.16	0.1 ± 0.04	0.05c
Pb*	0.12 - 1.52	0.36 ± 0.28	0.14 - 0.33	0.23 ± 0.06	0.3a

For all vegetables, PTEs were significantly higher in Kilembe mine area than controls ($P<0.05$)

The quality of public water sources and domestic water

Water source	Domestic water N = 37		Public water N = 20		Control samples N = 11		Drinking water threshold
Element	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	
PH	6.2 – 7.8	7.4 ± 0.3	6.7 – 7.8	7.2 ± 0.3	7.1 – 7.5	7.2 ± 0.1	(6.5–8.5) e & f
Salinity	0.0 – 0.3	0.0 ± 0.1	0.0 – 0.1	0.0 ± 0.0	0.0 – 0.1	0.0 ± 0.0	
TDS (ppm)	9 - 301	47.3 ± 46.9	26 - 91	40.2±17.5	36.0 – 59.0	48.8 ± 7.7	1000e & f
Al*	11.7 - 284.6	58.0 ± 47.8	14.4 – 135	62 ± 35	16.5 – 40.0	28.1 ± 7.4	200c & f
Cr	0.2 - 5.9	0.8 ± 0.9	0.2 – 3.6	0.7 ± 0.8	0.2 – 1.5	0.5 ± 0.4	100b, 50f
Mn	0.7 - 68.9	5.1 ± 11.9	0.9 – 146.7	21.4 ± 42.5	1.1 – 16.0	3.4 ± 4.3	400a, 100f
Fe*	11.3 – 448.5	117.2 ± 118.5	12.2 – 899.6	288.8 ± 295.8	19.2 – 179	74.5 ± 55.1	200c, 300f
Co*	0.0 - 123.3	4.3 ± 20.6	0.0 – 152.3	26.6 ± 53.4	0.0 – 0.2	0.08 ± 0.05	40d
Ni	0.2 – 21.5	1.6 ± 3.5	0.4 – 27.1	6.18 ± 10.4	0.4 – 7.7	1.4 ± 2.1	70a, 20f
Cu	0.8 – 46.9	5.4 ± 8.6	1.4 – 148.1	28.0 ± 47.3	0.7 – 42.7	6.6 ± 12.4	2000a, 1000f
Zn	2.9 – 126.3	23.6 ± 26.3	5.8 – 360.8	31.7 ± 77.9	6 – 2244	236 ± 667	3000a, 5000f
As	0.0 – 0.3	0.11 ± 0.06	0.1 – 0.3	0.1 ± 0.1	0.0 – 0.4	0.1 ± 0.1	10a & f
Cd	0.0 – 0.1	0.02 ± 0.01	0.0 – 0.1	0.0 ± 0.0	0.0 – 0.4	0.0 ± 0.1	3a & f
Pb	0.1 – 3.0	0.7 ± 0.6	0.5 – 1.3	0.8 ± 0.3	0.4 – 1.2	0.7 ± 0.3	10a & f

For all samples, PTEs in Kilembe water samples were significantly higher than controls ($p<0.01$)

Elements in toe nails

	Kilembe residents (N=31)		Controls outside Kilembe (N=18)		(P) value (2 sample T-test)
Element	Range	Mean ± SD	Range	Mean ± SD	
Na	49.4-2400	586±535	44-935	265±307	0.039
Mg	64.5-1010	253±197	6.9-120	57±34	0.000
P	83-1045	431±253	10-372	147±111	0.000
S	3826-33405	16641±8332	130-22470	7342±6649	0.005
K	123-3104	849±719	60-670	260±243	0.001
Ca	232-3210	1203±726	26-626	336±210	0.000
Al	*45.4-2648*	*524±568*	*3.62-546*	*176±180*	*0.006*
Cr	*0.02-11.1*	*1.2±2.1*	*0.04-1.3*	*0.4±0.4*	*0.043*
Mn	*2.3-81*	*23±21*	*0.3-23.6*	*7.9±7.4*	*0.003*
Fe	*46-3098*	*23±21*	*2.6-932*	*243±299*	*0.035*
Co	*0.04-4.7*	*0.8±0.9*	*0.007-0.6*	*0.18±0.2*	*0.003*
Ni	*0.25-43*	*3.7±7.5*	*0.11-2.9*	*1.4±1.1*	*0.12*
Cu	*1.2-34.5*	*7.4±7.1*	*0.09-3.4*	*1.5±1*	*0.000*
Zn	*16-163*	*69.7±34*	*0.9-65*	*26±18*	*0.000*
As	*0.02-0.7*	*0.2±0.17*	*0.01-0.14*	*0.05±0.04*	*0.000*
Sr	*1-14.8*	*5.3±3.5*	*0.1-1.4*	*0.9±0.4*	*0.000*
Pb	*0.05-2.1*	*0.62±0.50*	*0.01-2.5*	*0.5±0.9*	*0.791*

Conclusions

- Exposures of Kilembe residents to toxic copper mine wastes containing PTE is leading to health complications
- Health complications confirmed through interviews with Kilembe residents and patient records from health facilities
- Respiratory, gastro-intestinal diseases and cancer more pronounced
- Children and younger adults appear to be more exposed and more affected
- Females appear to be more affected by the diseases related to mine waste exposures
- Respiratory and gastro-intestinal diseases are more common with ulcers almost affecting all households
- Cases of cancer are also registered though in relatively smaller numbers

Recommendations

- Tailing erosion containment should be prioritized
- Cultivation of polluted soils should be discouraged
- Residences below tailing sites and along river Nyamwamba should be discouraged
- Collection of domestic water from River Nyamwamba and water wells within Kilembe valley should be discouraged
- An extensive health survey that involving diagnosis of affected populations in the context of their exposures need to be conducted to provide adequate data for risk assessment
- Investigation of risk factors associated with gender and age
- Sensitisation of affected populations should be an ongoing process

(just like the HIV/AIDS awareness)

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Challenges faced

- Lengthy process of obtaining IRB (almost one year)
- Superstitious beliefs among residents in Kilembe, un willing to provide biomarkers (toe nails) and house dusts
- Costly laboratory procedures that cannot be done locally

Post doc outputs

- MSc. Student (Mr. Ekiryagaana Martin) graduating in Feb 2023
- Disseminations done in Kilembe and Kasese district local government
- Policy briefs distributed to NEMA, MEMD, MWE and other stakeholders
- 2 manuscripts developed and being polished for submission
- A video documentary on youtube with over 1500 views
- https://www.youtube.com/watch?v=cU9o33XK8CQ&t=665s

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- Kasese district local government technical staff

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