A review paper on traditional fuel use, indoor air pollution, and Respiratory diseases: Lessons for South Africa

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Abstract— About 90% of the South African population have got access to electricity, yet it is believed that several households continue to rely on traditional fuels such as coal, charcoal, firewood, animal dung as their primary cooking fuels. The combustion of traditional fuels in an inefficient cookstoves results in increased Indoor Air Pollution (IAP), ill respiratory health and several cases of premature deaths. This paper summarizes studies providing evidence of an association between household energy patterns, IAP and of acute or chronic lower and upper respiratory infections in South African households. It is believed that IAP has contributed to about 1400 premature deaths and current interventions programmes to increase access to modern energy services including electricity for poor households could be failing as reports of diseases and deaths continue to be documented. Based on existing evidence, it is that recommended energy practitioners should target achievable, yet health-saving interventions targets for the poor.

Index Terms— **Energy use, indoor air quality, respiratory diseases**

1 INTRODUCTION

Globally, about 2.8 billion people rely on traditional fuels including coal, charcoal, firewood and animal dung as their primary cooking energy source. The people most affected are amongst the world poorest and live mostly in developing countries, South Africa is not excluded [1].

The burning of traditional fuels for household cooking, heating and illumination is common practice in South Africa [2], [3]. It is believed that despite having over 90% electrification rate [4], there is still a good proportion of South African households who are dependent on multiple fuels such as charcoal, kerosene, coal, firewood, with the latter three used by more than 70% of poor households [2], [5], [6], [7]. Poverty and fuel associated costs are amongst other motivating factors. However, resulting health outcomes should be of great concern, especially in the twenty-first century [7], [8], [9].

The use of traditional fuels for cooking, heating, and illumination is associated with the burden of disease chronic and acute in affected households [9], [10], [11], [12]. Every year, incidences of child and mother maligned respiratory health are reported in the public domain, the resulting leading to premature morbidity [8]. Regarding morbidity, it is documented that IAP claims about 1400 children lives annually in households who depend on these fuels [8], [9]. Recent, cases of shelter burn-down, child injuries and burns have also been documented [13].

With the view of the above, this paper employs traditional review methods to present summative findings from studies on household energy patterns, IAP and respiratory health in South Africa. The paper ends by narrowing on previous and current interventions to reduce dependence on these fuels and decrease disease burden in affected households.

2 ENERGY USE, IAP, AND RESPIRATORY HEALTH

This section summarizes existing energy use scenarios studies and discusses combustion emissions and how they relate to the respiratory disease burden in South Africa.

2.1 Energy Use Scenarios in South African Households

The most frequent types of energy used in poor South African households include coal, firewood, kerosene, and candles [3], [4], [5], [6]. Coal is the primary cooking fuel especially in the Highveld where it is mined, but this fuel is also found in some other areas of the country where it is not mined [31]. Low-income households in coal-abundant areas acquire the fuel from the local merchants and burn in several types of domestic cookstoves including local brazier, also called imbaulas [4], [6], [23]. In addition to socio-economics of the household, coal use in South Africa is also linked with culture [6]. Previous studies have reported that households prefer using this fuel due to the pleasant aroma it gives to their food [6]. Whether that is true or not has not been investigated yet. However, the use of this fuel has more to do with financial comfort and its availability [4].

The other household cooking fuel found in abundance in South Africa is firewood. Firewood is used as the primary cooking fuel especially in areas where coal is not abundant [31]. As opposed to coal, wood is readily available at no charge in most localities where it is used [32]. When considering the cost factor, minimal money is spent by a household to acquire the fuel [70]. However, its use becomes associated with high cost during the rainy season where most reserves are damaged by the rainwater [6]. Wood costs are

"This work was supported in part by the University of the Witwatersrand, the National Institute for Occupational Health, the University of Johannesburg, and Ehlanzeni District Municipality."

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also high when households depend on this fuel, especially in areas where it is not found in abundance [32].

Moreover, household cooking and heating in South Africa is done using other energy sources including gas, charcoal and kerosene [13], [23], [51], [71], [72]. Although these fuels are not widely used like coal and firewood, they form an important basis of the household energy sources [48]. Charcoal is especially used in the Eastern Cape province, while the use of gas and kerosene can be traced throughout South Africa [71], [72]. Also, kerosene is used for illumination [6], [13]. However, candles are often the primary energy source for illumination in non-electrified households [70]. It is evident that the use of all energy sources is primarily motivated by the socio-economics of the households [3], [13]. Most energy use scenarios studies have stated that households report high cost of electricity as a hindrance to using this fuel for most of their energy demanding activities [31], [70]. Often, when they can afford electricity, illumination and entertainment are prioritized over cooking [31].

2.2 **Energy Use and IAP**

In general, the pollutants from traditional fuel combustion are the same for all the fuels so far mentioned in this paper. However, in the section below, emissions from individual fuels are discussed and emphases on the most use in South African rural household.

2.2.1 Coal

The use of coal differs per province, this is due to availability (see Fig 2.1).Several studies have associated coal burning with emissions of detrimental pollutants including carbon monoxide, carbon dioxide (CO), nitrogen compounds, sulphur dioxide (SO_2), particulate matter and hydrogen sulphide [25], [38], [39]. While it is known that most pollutants from domestic coal combustion are emitted throughout the different combustion phases, some pollutants are found in high concentration, especially as the fuel has not completely combusted (this includes CO and particulate matter). Particulate matter is variant in size, but the one public health importance is PM_{10}, fine and ultrafine particles. However, fuel emissions and their concentrations are not only a factor of energy patterns but the appliances as well.

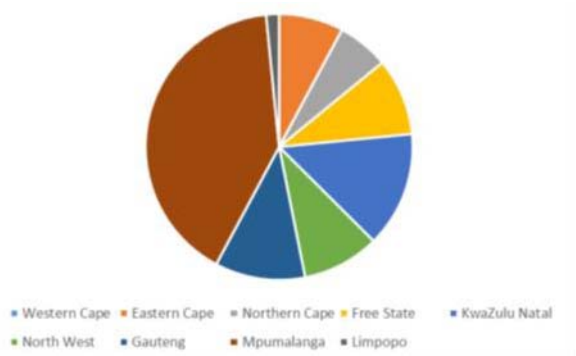

Fig 2.1 Coal use per province in South Africa

2.2.2 Firewood

The use of firewood is the second most used fuel (see Fig 2.2) and has been associated with the highest count of pollutants in comparison to other fuels. It is believed that wood smoke alone contains copious amounts of emissions relative to other pollutants previously mentioned [25]. However, the smoke from domestic wood combustion can also not be compared to coal and kerosene smoke [28]. If concentration matters the most, then it can be said that wood smoke plays a crucial role in household burden of disease from domestic coal combustion [27], [28], [34]. Other emissions from wood smoke include polycyclic aromatic hydrocarbon, a human carcinogen also found in coal [66].

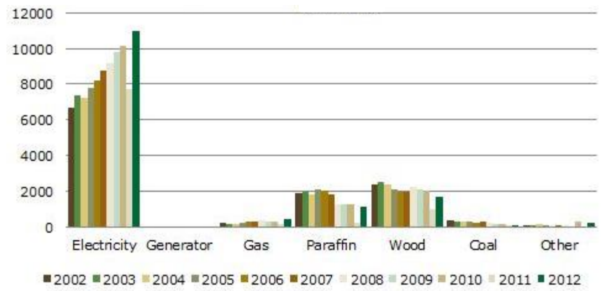

Fig 2.2: Energy sources for cooking.

Recent, scientists have emphasized on pollutant properties including form, morphology, and size as important factors of their toxicity [38]. Hence the need to isolate aerosol particles as emissions from wood and coal combustion. It is believed that aerosol emissions could bear-traces of harmful chemicals which can exacerbate the toxicity of emissions [62].

2.2.3 Kerosene and candles

Thus far, it is seen that most pollutants from fuel combustion are embedded in smoke, which escapes as the fuel burns [73], [74], [75]. It is also evident in kerosene and candles. These fuels which are highly used for illumination (see Fig 2.3) are associated with black carbon emissions, and high number of fine and ultrafine particles including phosphates or alkali and nitrates [73], [74], [75]. Agglomerated elemental carbon is one pollutant of public health importance [73]

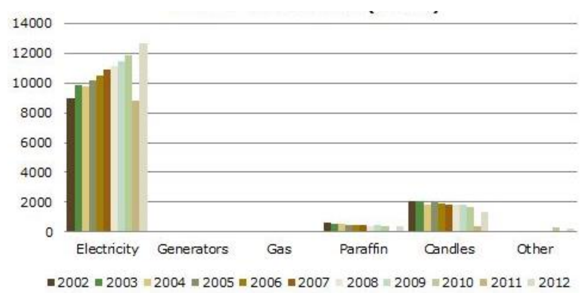

Fig 2.3: Energy sources for lighting from 2002 to 2012 per 1000 households

2.2.4 Energy Appliances

It is believed that emissions from domestic fuel combustion are also a function of cookstoves [23]. The feature of the household cookstove with high impact on emission properties is the stove ventilation rates [24], [27]. Studies on household cookstove design have often stated that poor stove ventilation contributes to escape of pollutants in high quantities, the case of the three stone cookstove (see fig. 2.4) [40]. However, an important factor is that most household stoves are self-fabricated, also owing to the role played by household socio-economics in energy use [23].

Previous studies on household stoves have identified that burning modalities to affect fuel emissions. Often, either of the bottom lift updraft (BLUD) or top lift updraft (TLUD) method can lead to high emissions of PM and CO, especially when the fuel bed has not been prepared well [25].

Fig.2.4 Indoor cooking in rural areas

2.3 Energy Use, IAP and Respiratory Health

Recent, there is ample information on association between traditional fuel use and household respiratory health [27], [28]. It was stated earlier that increase in ill health is a function of household energy sources patterns and appliances, not merely fuel use only. The previous two sections deliberated on emissions from fuel burning while also including the potential contribution of cooking appliances. Some of the pollutants from domestic fuel combustion listed in the last section included CO, PM's, nitrogen compounds and other inhalable matter [12], [25], [39]. Exposure to CO and PM's, especially $PM_{2.5}$ has been associated with increased risk of lower and upper respiratory infections including a persistent cough and chronic obstructive pulmonary diseases [27], [28], [52], [53]. It is also reported that emissions from domestic combustion induce the risk of asthma, shortness of breath, and recent lung cancer which has been associated with coal smoke [34]. Existing health reports include self-reported studies as well as experimental studies [28], [29].

Despite extensive status of knowledge on the topic being debated, to date, there is a dearth of information in South Africa on household cooking fuels and respiratory health [20]. We explored some of the existing studies with no limitation in time to extract as much information as possible. Research on IAP from cooking fuels and respiratory health has been going for decades. For instance, in the 1990's scientific investigations were sought to find a correlation between IAP and households respiratory diseases [54], [55]. Early reports documented an increased risk of lower and upper respiratory infections from domestic coal burning. The highest peak of ill health was reported in children below the age of 5 years and the elderly [54], [55], [56]. Moreover, Nel et al. [52], found similar associations in children of households where wood was used in addition to coal for purposes of cooking.

Moreover, in the early 2000's Wichmann and Voyi explored the prevalence of acute respiratory health in children under the age of 5 years using data from national health and demographic surveys [57], [58]. They found that approximately 30% of children living in households where biomass and liquid fuels such paraffin were used, experienced lower respiratory infections. After controlling confounding, Wichmann and Voyi reported a relative mortality risk of 1.95 [59]. Other studies have shown an improved health status after the elimination of the source of exposure [60]. This result is consistent with findings in Sanyal and Maduna [60] where it was shown that some high level of recurring respiratory infections was experienced amongst children in the Eastern Cape Province of South Africa after being exposed to coal and firewood emissions. A review study by Barnes et al. also showed evidence of acute lower respiratory infections between age of two and four years amongst children living in households polluting fuels compared to households who use electricity [20].

Furthermore, there exists literature on IAP from household fuel burning that has not necessarily stressed on respiratory health [61], [62]. However, these studies have highlighted cause for concern as stressed by Barnes et al. Mostly, reports emerge of possible exceedance of household air quality standards for pollutants of public health importance including CO, PM's, NO2 and SO2 [61], [62], [63]. Incidences of potential exposure to these pollutants were done during household cooking or under laboratory conditions [62], [63]. Several studies from the health reports have being conducted. Between 2007 and 2012, it was estimated that about 1400 lives in South Africa are prematurely lost as result of IAP per annum, [8], [9], [64]. Approximately half of this number include children below the age of 5 and are affected by acute lower respiratory infections [65].

The findings from this review are consistent with information from international and African literature [34]. It is documented that IAP has triggered the causation of several respiratory diseases in countries such as Ethiopia, Kenya, India and China [66], [67], [68]. Premature morbidity was also one the health outcomes in these countries [67]. However, in all these countries there have been interventions to target the health burden of IAP [46]. The question we ask is: "Has there been any energy interventions in South Africa aimed at reducing the health burden of IAP from domestic combustion?" "If there has been, how does it compare to present health reports mortality rates related to IAP?"

3 LESSONS FROM CURRENT PUBLIC HEALTH INTERVENTIONS

In curbing the public health challenges associated with domestic use of traditional energies, IAP, and respiratory diseases, the government of South Africa has embarked on several types of energy/ fuels interventions programmes [14], [15].In 1994, government introduced 1994 the National Electrification Programme (NEP) in order provide electricity at fast rate for poor and disadvantaged communities [76]. However, government could not provide electricity to the need as planned due to affordability by the disadvantaged communities and government came with social tariff intervention. [77], [78]. One such popular intervention is the free basic electricity (FBE) programme [16]. The FBE programme was first launched in the early 2000's to reduce domestic burning of traditional fuels while supplying poor households with a minimum amount of grid electricity energy [17]. The given amount varying from areas could thus complement household's energy needs for cooking, heating, and illumination [17]. However, recent literature reports have stated that despite this programme being extend to about 1.8 million South Africans, the use of traditional fuels especially for cooking and heating is still commonplace in poor South African households [3], [4]. The lessons learned are that the provided electricity units cannot aid households to cover their current energy debts [18]. Moreover, based on the income status, poor South African households can still not afford relying on electricity alone [4].

While the FBE has had its successes and challenges, the government also launched another intervention with similar objectives of reducing dependence on traditional fuels. The intervention was launched during the same time interval with the FBE policy implementation and saw the value-added tax removed from most liquid fuels used by households in South Africa [19]. In a way, this intervention will help loosen the burden associated with liquid fuel sale prices, while encouraging extensive use of these fuels in poor households [19]. The lessons learned are that the programme has been a large success in targeted households, however, it also brought about important public health issues within several communities [13]. Studies that have evaluated the programme reported increased incidences of respiratory diseases in exposed communities [20], [21], [22]. Recent the increase in shack fires, child burns, household injuries and even mortality [13].

The previous intervention also came with the introduction of low smoke fuels, Basa njengo Magogo (BnM) and improved cookstoves in the so-called needy communities. In 1994, research work commenced on a low smoke fuels with first experiments in South Africa conducted during 1997[12]. This lead to the introduction of BnM started in Mbalenhle. The method was to cover the coal with dry twigs and paper and then lighting this kindling from the top, instead of from the bottom. It create a hot zone at the top of the fire, less smoke is emitted per unit of coal combusted [63]. It had its success but it failed due to community by-in, as the Department of Energy, noted that the community went back to what the know. Most be leaved it took too long to heat up. Hence, the reason it was not sustainable. From early 2000 to date, several improved cookstoves have been disseminated throughout South Africa [23], [25]. These stoves are believed to abate or even eliminate emissions associated with fuel burning in households, thus reducing the disease burden from traditional fuels' burning [23]. However, evidence from literature has also proved that many of the so-called improved cookstoves have not achieved the targeted goal [25]. Field and laboratory investigations have associated improved cookstoves with emissions of harmful pollutants, which still exacerbated the disease burden in poor communities [25]. It is also believed that these stoves are not sustainable, hence increased calls for rejection of these stoves in communities [21], Similar findings have also been reported in other developing countries where improved cookstoves have been given to households [26], [27]. Besides reports on the disease burden, households have reported multiple failures of the stoves, hence continuous reliance on self-fabricated stoves [28], [29].

Furthermore, it is believed that countries, whether developed or developing, have succeeded with interventions on reducing and eliminating dependence on traditional fuels and decreasing households' burden of disease from fuel use [46], [47]. Some of the recent interventions include the introduction of alternative clean energy sources such as LPG, solar and even electricity to a large extent. Regarding LPG, countries in Southern Africa have extensively used these means [48], [49], [50]. Positively resulting in a reduced IAP and subsequent offset in new cases of diseases [50]. Electricity and solar are the most widespread of clean energy programs but could require extensive financial resources to be fully implemented [4].

While the South African government can target this intervention in future, the most eminent way of reducing IAP and respiratory diseases at the present moment could be the dissemination of LPG pipelines in clean energy-needy communities [51]. It is believed that child exposure to IAP is significantly reduced by promotion of behavioural change, which could consequently benefit greatly on children's respiratory health [30]. However, this study has established a need for proactive approach to be considered to reduce exposure to IAP. In order to guarantee the success of such intervention, (1) funds need to be raised by concerned role players and actioned toward the programme. Also, (2) the dissemination of LPG is a means for encouraging small business and entrepreneurship in communities already characterized by poverty. Poverty is one of the principal factors of traditional fuel dependence. Therefore, by creating employment for themselves, households generate income and could start thinking of switching to alternative clean fuels in future.

4 CONCLUSION

The review highlights evidences of association between household energy use, IAP and respiratory symptoms. Although research studying association between IAP and respiratory health in South Africa are very limited, there are several lessons that can extrapolated from these researches and others in other countries. In light of the current evidence on ill respiratory health and the failure of previously promulgated interventions, there needs to be a much greater emphasis on targeting the barriers to the failure of the interventions.

5 ACKNOWLEDGEMENTS

This research was supported by the University of Johannesburg, Department of Environmental Health, University of the Witwatersrand and the National Institute for Occupational Health. I would also like to thank Mr. S. Mgwambani for valuable insight.

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