Substance abuse in the Western Cape Province of South Africa: insights through mathematical modelling

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Methamphetamine use

Methamphetamine is a highly addictive stimulant of which the production and abuse has increased dramatically in South Africa, with similar trends having been observed in the United States during the past decade (1). It is a cheap street drug with a variety of forms and street names. It is commonly known as "tik" in South Africa (2) and was introduced through gangs in affected communities. The common effects of intoxication are increased energy and self-confidence, euphoria, heightened libido and appetite suppression. Prolonged use is usually characterized by severe weight loss, mood swings, violent behaviour and body organ disorders (2 - 4).

In recent years there has been a dramatic increase in treatment demand for abuse of drugs such as dagga, mandrax, cocaine, heroin and methamphetamine (MA) in the Western Cape Province (WCP) of South Africa. The number of MA patients - defined as drug users who used MA as a primary substance of abuse - who enrolled into treatment centres in the WCP went from zero in the second half of 1996 to 1209 in the first half of 2008, and peaked in the second half of 2006 (1451 patients) (Table 1).

abuse?", "How does drug abuse impact diseases dynamics?", "What preventive measures should we adopt?" to "What are the costs of prevention?". Preventive measures are aimed at reducing drug initiation and maximizing treatment opportunities. It is thus important to understand and measure drug use (7). Mathematical models can help in predicting drug use trends, designing interventions, and evaluating their success (8). Therefore, they represent a powerful tool in modelling drug abuse dynamics in any given population.

It is against this background and the implications of MA abuse for public health in the WCP, that a model was formulated to study the dynamics of treatment use for MA abuse in the WCP, with the aim of providing a predictive tool for the prevalence of drug use.

The model consists of four compartments of susceptible individuals at risk of using MA: light MA users, hard MA users, clients of health care services in treatment and permanent quitters. The most important assumption of the model is that the rate at which drug use spreads in the population mirrors that of a disease. So, the rate of generation of new cases depends on the existing cases of drug

Table 1. Number of MA patients in treatment centres in the WCP (1996-2008) (5)

Year	96b	97a	97b	98a	98b	99a	99b	00a	00b	01a	01b	02a
MA users	0	0	2	0	1	2	6*	10*	12*	14*	17*	21*
Year	02b	03a	03b	04a	04b	05a	05b	06a	06b	07a	07b	08a
MA users	32	81	121	429	668	884	952	1232	1451	1413	1356	1209

* indicates estimated values from use of MA as a primary substance of abuse.

Drug abuse and the burden of drug use is also greater in the WCP when compared to other provinces in South Africa (5). MA use has been linked to risky sexual behaviour and sexually transmitted infections including HIV (2,6). Thus, MA use has immense public health implications.

Substance abuse research

Drug abuse and its impact on societies present a vast and complicated field of research (7). The research questions range from "What is the prevalence of drug use?", "How do drug use patterns change?", "What are the consequences of drug

users and the number of non-users at risk (7). Light drug users are allowed to pass through a period of concealed drug use at the beginning. It is at this stage that one can easily stop and recover from drug use. The period of concealed drug use is followed by the problematic phase of addiction. Continued use of drugs usually results in criminal, health and social problems that are identifiable and it is at this stage that assistance in the form of treatment is instituted. The model allows for the recovery of those under treatment into a class of permanent quitters. This is because treatment for drug users is currently restricted to treatment centres and individuals are released from treatment centres when

they have recovered. So the model assumes that a relapse can only occur after individuals have recovered. Furthermore, it assumes that upon relapse, an individual is more likely to become a hard drug user again than being a light drug user due to familiarity in drug use. There are no fast progressors, i.e. individuals who immediately become hard drug users after an initiation. Treatment is assumed to be on an "inpatients" basis.

In order to model aspects related to behaviour change an exponential function is included in the incidence function. The function modelled behaviour change induced by the adverse effects of addiction related to mortality. The same function has been used by a number of researchers to model behaviour change and the impact of information campaigns (9,10). Inclusion of behaviour change increases the non-linearity of the incidence function and thus simulations were done.

Predicted prevalence of MA use

Drug abuse patterns in the Western Cape are largely driven by patterns in Cape Town. The city of Cape Town has experienced a large growth in the past years, mainly due to migration from other provinces, especially the Eastern Cape (1).

Unemployment and poverty, especially in the Cape Flats (the low-lying, flat area situated to the southeast of the central business district), has been related to the sharp increase in criminal activities that include a highly organized illegal drug economy (4). As an application of the model it was fitted to data from the South African Community Epidemiology Network on Drug Use (SACENDU) (5). Due to the unavailability of data on transmission and progression rates, most of the parameters were estimated using assumptions on the drug epidemic (party based on literature). The epidemic is modelled as from 1996, because of the availability of documented data from that date. Data on treatment demand trends is used to model the change in the number of individuals in the compartment of individuals under treatment. Figure 1 is a graphical representation of the model fitted to data for individuals seeking treatment for MA abuse. The circles represent the actual data and the continuous line the fit from the model.

The least squares method (LSM) used in the fitting process, generates parameter values for the estimated parameters. Using the generated parameters that give the best fit, the prevalence curve given in Figure 2 could be plotted.
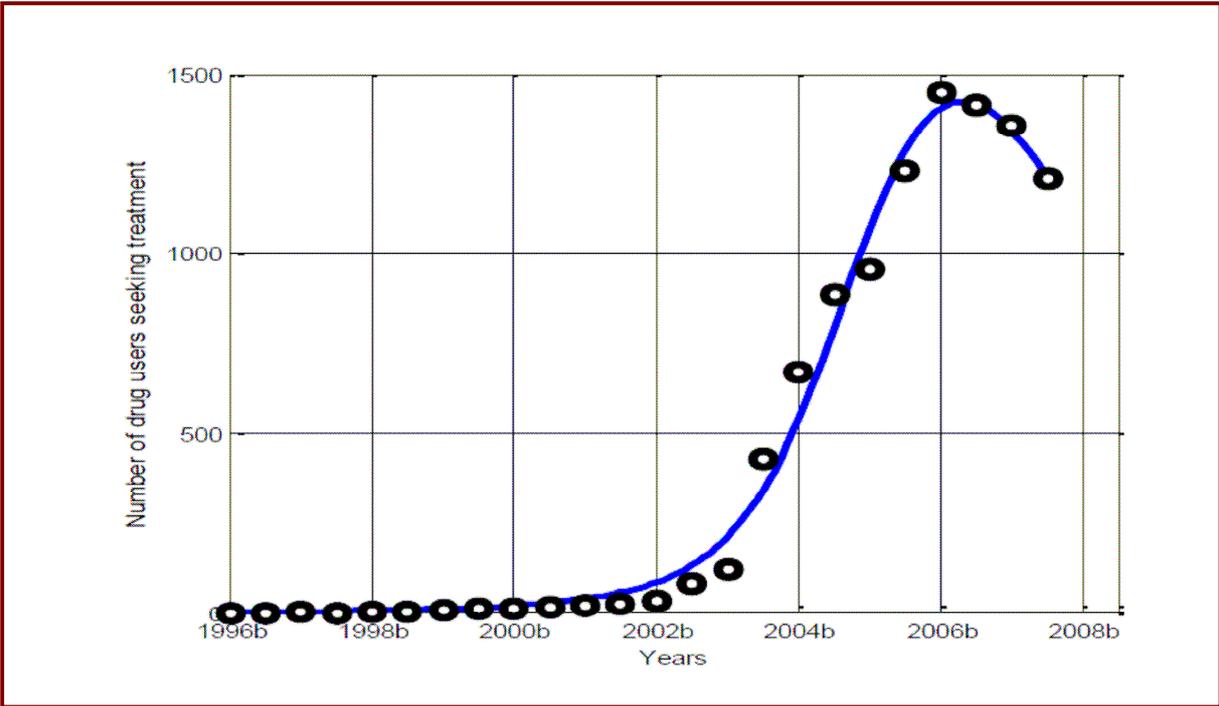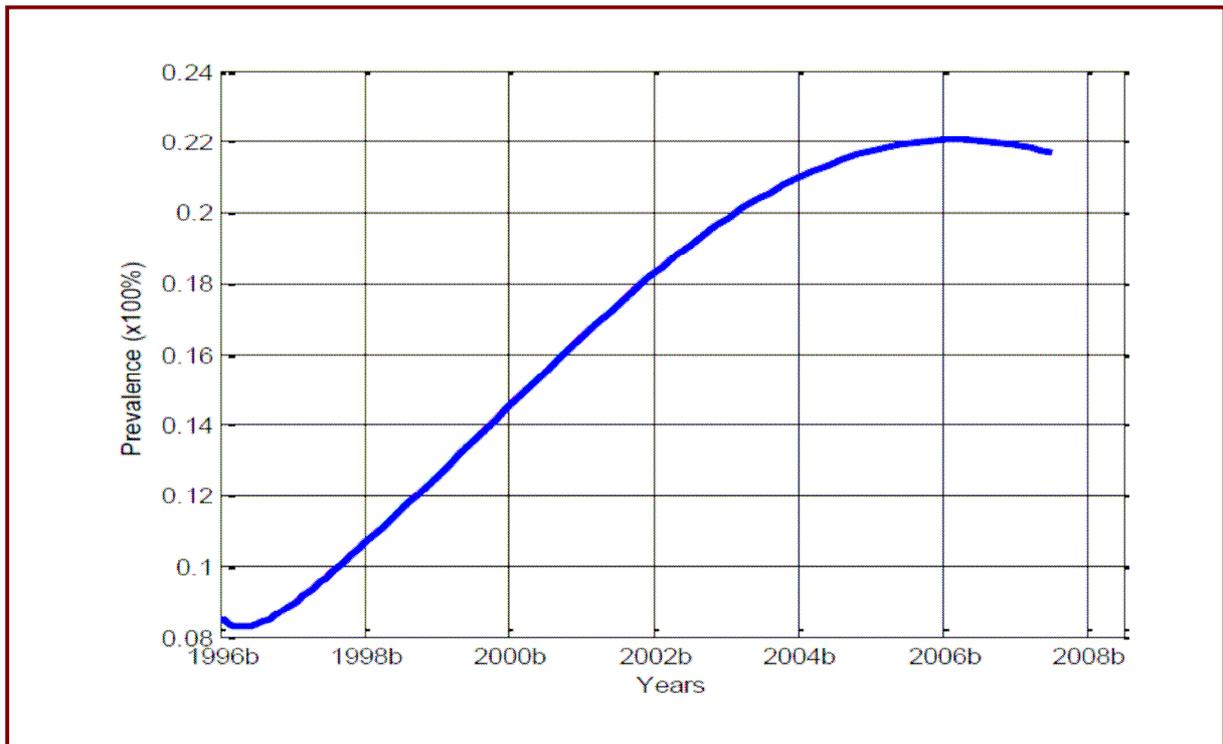

Figure 1. Individuals seeking treatment for MA use

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Figure 2. Prevalence curve for the MA epidemic

The rapid increase observed in the number of individuals seeking treatment may have been an indication of a rapid increase in the number of MA users in the community as shown by Figure 2. The graph shows that the prevalence has actually peaked and is now on a slight decline. For a population of 1 million individuals in the Cape Flats, a prevalence of 20% implies that the population of MA users will be approximately 200 000. This compares well to the estimated number of MA users in Cape Town (11).

Interventions

While the epidemic presents impeccable challenges, interventions have been put in place. These include reducing the supply of drugs to the communities, promoting intervention programs associated with behaviour change and improving access to quality treatment. The adverse effects of drug addiction, often leading to death, can lead to behaviour change. Such observations have been made for diseases such as HIV, where deaths due to the disease can induce behaviour change. This informed the formulation of the function that models behaviour change.

Through the analysis of the model reproduction number, that is, the mean number of new initiates generated by one index case in a population that is entirely susceptible, the following was noted:

1. The model has a unique endemic equilibrium whenever the reproduction number is greater than one, indicating persistence of drug users in the community. The reproduction number is thus a threshold value that determines the persistence of MA abuse.

2. The number of drug users can be reduced by reducing the reproduction number, through a reduction in the contact rate, increased behaviour change and increased interventions at the light drug user phase that lead to recovery.

3. Increased behaviour change can reduce the prevalence of drug users in the community.

The current model has some limitations. The MA epidemic in Cape Town has, to some extent, been exacerbated by drug lords who target innocent school children in disguise by selling them sweets tainted with drugs. The model does not take that into consideration. The transmission and progression rates are not well documented for the Cape Town setting and as such, a totally accurate prediction of the real scenario is not possible. The model does not take into account the social dynamics of communities that are affected by MA use and these are the very factors that are at the core of the MA epidemic dynamics. The idea is to extend the model to include these factors, including age structure, the effect of information campaigns and the effect of drug lords.

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