Modelling "Tik" abuse in the presence of drug-supply chains

Farai Nyabadza - Senior Lecturer, Department of Mathematical Sciences,
Stellenbosch University

John Boscoh H. Njagarah - PhD student, Department of Mathematical Sciences,
Stellenbosch University

Robert J. Smith - Senior Lecturer, Department of Mathematics,
The University of Ottawa, Ottawa, ON Canada.

Methamphetamine (MA), commonly known by the street name “tik” in South Africa, is a highly addictive stimulant whose production and abuse has increased dramatically in South Africa (4). Since its advent in 1893, in Japan, the abuse of “tik” remains a major global health and social problem (2). Its popularity stems from energy-promoting and performance-enhancing properties. It also gives users appetite suppression and it is this very property that drug-supply chains have taken advantage of by luring young women, who would not be typical drug users, into taking “tik” as a weight-loss remedy. In South Africa, “tik” is sold in drinking straws, with prices being charged per straw. The bitter white powder is usually placed in the glass enclosure of an incandescent light bulb, heated with a lighter and the fumes inhaled (1).

Generally, research into drug abuse and its impact on the general population presents an insurmountable task. In South Africa, many questions remain unanswered as to how prevalent is drug abuse and the implications of drug use, especially on disease burden, healthcare and budgetary demands as well as risky behaviour. This raises questions on what policies should be put in place and how these can be evaluated. There is a need to understand the problem, measure drug use trends, design appropriate intervention measures and evaluate the success of these interventions (3). It is at this stage that mathematical models become useful. Mathematical models can help in designing interventions, evaluating their success and predicting drug use trends (8).

Modelling the “tik” epidemic

A few decades ago, many researchers have alluded to drug abuse spreading like an infectious disease (6, 9, 10). Their focus has mainly been the modelling of heroin epidemics. The dynamics of smoking (whose mode of transmission is closely related to that of drug use) have also been modelled recently (7, 8, 11–13). In these models, the rate of generation of new drug users depends on contacts between non-drug users and drug users. In this paper, in addition to the bilinear interaction that generates new cases, we also take into consideration the role played by drug-supply chains and person-to-person initiation in fuelling the “tik” epidemic.

We extended the compartmental model presented in an earlier study (11) that provides a structure in which numbers of individuals in each compartment can be tracked in time as relationships between compartments described in mathematical terms evolve.

The overall number of “tik” users and those under 20 years of age seeking treatment for “tik” as a primary drug of abuse in the Western Cape Province of South Africa is second to no other province in the country. This is in spite of the growing number of rehabilitation centres in the province. The proportion of all drug users seeking treatment for “tik” as the primary drug of abuse has increased from zero in the second half of 1997 to 33.6% in 2010 with peak value of about 42.7% in the second half of 2006 (Table 1).

<table>
<thead>
<tr>
<th>Year</th>
<th>97a</th>
<th>97b</th>
<th>98a</th>
<th>98b</th>
<th>99a</th>
<th>99b</th>
<th>00a</th>
<th>00b</th>
<th>01a</th>
<th>01b</th>
<th>02a</th>
<th>02b</th>
<th>03b</th>
</tr>
</thead>
<tbody>
<tr>
<td>% ‘tik’ use</td>
<td>0.0</td>
<td>0.1</td>
<td>0.0</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.2</td>
<td>0.1</td>
<td>0.1</td>
<td>0.3</td>
<td>0.3</td>
<td>0.8</td>
<td>2.3</td>
</tr>
<tr>
<td>Year</td>
<td>04a</td>
<td>04b</td>
<td>05a</td>
<td>05b</td>
<td>06a</td>
<td>06b</td>
<td>07a</td>
<td>07b</td>
<td>08a</td>
<td>08b</td>
<td>09a</td>
<td>09b</td>
<td>10a</td>
</tr>
<tr>
<td>% ‘tik’ use</td>
<td>10.7</td>
<td>19.3</td>
<td>26.1</td>
<td>34.7</td>
<td>37.2</td>
<td>42.3</td>
<td>40.7</td>
<td>36.1</td>
<td>35.8</td>
<td>35.1</td>
<td>40.6</td>
<td>35.5</td>
<td>33.6</td>
</tr>
</tbody>
</table>

The main objectives of this paper are; first, to develop a mathematical model that takes into account rehabilitation, improvement and policing of drug-supply chains. Secondly, to fit the model to observed data on individuals under rehabilitation and determine the corresponding incidence of "tik" use using the parameters that produce the best fit to the data. Lastly, we also endeavour to quantify the levels of policing and determine the impact of increased or decreased policing on the dynamics of "tik" abuse. The assumption is that drug users fuel the growth of supply chains and new drug initiations arise through both exposure to drug-supply chains (run by drug lords) and through person-to-person contact.

The model used consists of five compartments describing the human population i.e. individuals who are susceptible to initiation into MA use, those who use MA occasionally (light users), heavy users, those in rehabilitation and temporary quitters. Drug supply chains are assumed not to be part of the general population. The major assumptions of the model are that, the population mixing is homogeneous and that substance use progresses like an epidemic. Therefore, that rate at which new drug users are initiated depends on (1) the number of those at risk of using drugs as well as those already using drugs and (2) initiations resulting from those at risk of using drugs interacting with drug suppliers and gangs. The conceptual model is innovative in three ways. First, it incorporates the density of drugs in the supply chains who are assumed not to be an integral part of the community. Secondly, it includes a recovery process that is ameliorative. Thirdly, it includes aspects of policing that are important in controlling the supply of drugs on the market. Light drug users go through a period of concealed drug use followed by a phase of hard drug use. Hard drug use may result into health problems and drug related dispositions which may require assistance from treatment and rehabilitation centres. The model allows for recovery of those in treatment as well as light drug users into a class of quitters. We assume that individuals who quit, should they relapse, will go straight into the heavy users class due to their previous exposure to drugs.

**Predicted prevalence and incidence trends**

The least squares curve fit method (lscurvefit) in Matlab is used in fitting the model to the data in Table 1 and was also used to generate parameter values that give the best fit (Figure 1).

The generated best fit parameters were used to generate an estimate of the trend of the new initiations over the modelling period (Figure 2). Figure 2 shows that new initiations into substance abuse peaked (around 2005) slightly before the peak values in prevalence were realised around the second half of 2006. The model predicts that new initiations into drugs use are reducing. We also observe that if policing targeting drug supplies is increased, this reduces the “tik” epidemic at a much faster rate.

![Figure 1: Drug users seeking treatment for MA as a primary drug of abuse](image-url)
Managing the “tik” epidemic

The results of modelling suggests that control of “tik” pivots around social intervention programs. Programs aimed at light drug users to encourage them to quit will be significantly more effective than targeting heavy drug users, either in quitting or in rehabilitation. Similarly, the person-to-person contact rate (which is more dependent on light users) may be reduced by social programs that raise awareness of the dangers of “tik” use and discourage light users from recruiting others. It follows that efforts to manage the “tik” epidemic will be significantly dependent on social programs. Therefore, it is critical to assess the population-level impact of “tik” use and to devote resources to education, awareness and quitting programs that are especially targeted to occasional users.

Through analysis of the initiation threshold (the model reproduction number), that is the average number of new initiates generated by a drug user or drug-supply in a purely susceptible population, we noted the following:

1. The model has a unique drug persistent equilibrium whenever the initiation threshold is greater than one. We note that when the initiation threshold is greater than one, the subsequent generation of “tik” users will be greater than their predecessors. Hence this indicates persistence of “tik” use in the community.

2. The number of drug users can be reduced in two ways: (1) reducing the contact rate through behavioural change and encouraging light drug users to quit, (2) through increased policing targeting gangs and drug suppliers which reduces the likelihood that a susceptible individual will be initiated into drug use through contact with supply chains. Therefore, policing increases scarcity of abusable drugs through seizure of such drugs and incarceration of drug dealers, prevents aggressive marketing of illicit drugs and legally penalizes identifiable (physiologically predisposed) drug users.

As no model is perfect, the model studied has the following limitations. The dynamic model of “tik” abuse considered, does not consider detailed social and economic characteristics (such as living conditions, literacy levels and household income) and simultaneous abuse of substances. It is necessary to extend the model to account for multiple drug abuse and social factors that drive the epidemic if it is to be contained.

Farai Nyabadza, Senior Lecturer, Department of Mathematical Sciences, Stellenbosch University. Areas of interest: Mathematical Biology. nyabadzaf@sun.ac.za

John Boscoh H. Njagarah, PhD student, Department of Mathematical Sciences, Stellenbosch University. Areas of interest: Mathematical Biology. johnhatson@sun.ac.za

Robert J. Smith, Senior Lecturer, Department of Mathematics, The University of Ottawa, Ottawa, ON Canada. Areas of interest: Mathematical Biology. rsmith43@uottawa.ca

References:


