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MATHEMATICAL MODEL ON THE CONTROL/MANAGEMENT OF THE METHAMPHETAMINE CONSUMPTION IN AFIKPO NORTH LOCAL GOVERNMENT AREA OF EBONYI STATE

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Abstract

The present work studied the dynamics of the interaction of the susceptible and victims of Methamphetamine consumption using a mathematical model SEIR (Susceptible, Exposed, Infected, and Recovered/Removed) approach with sensitive control parameters introduced accordingly. We strive at developing a set of model equations from a schematic diagram designed as to enable us conduct some necessary analyses for the study. We derive a deterministic model on the consumption of Methamphetamine in Afikpo Local Government Area of Ebonyi State via (a). Developing proper and all-encompassing schematic diagram from the necessary differential equations will be generated for use for the research analyses, (b). Introducing/employing of ideal control parameters or measures at the right/vital compartments in the schematic diagram, (c). Conducting the three (3) relevant/basic analyses such as (i) Stability, (ii) Endemicity, (iii) Sensitivity analyses of the model equations, (d). Simulating the system using a derived sensitivity index table with the help of R_0, and (e). Interpreting the resulting graphs that will provide the effective control measures on the use of Methamphetamine. It is discovered that our control parameter $\boldsymbol{\tau}$ which is the enlightenment control to avoid the use of methamphetamine is the most effective control measure in respect to the dangers associated with this substance.

Keywords: Methamphetamine, Control measure, Reproductive number.

Introduction:

Methamphetamine has been in use as early as World War II (1995) whensoldiers used it to boost their morale and to reduce fatigue and suppress appetite in the United States of America (Ashton, 2001). In the 1950s and 1960s, methamphetamine was being prescribed as medication for depression and obesity that reached a peak of 31 million prescriptions in U.S as at then.The neurocognitive, neurotoxic effects as well as the psychoactive related issues brought about the significant public health concern globally (Ayenigbara, 2014). Itsneurocognitive deficits via behavioral and neurocognitive paradigmsattracted our concern and we decided to do some mathematical analysis as to x-ray the height of mental damage being inflicted on our youths by this substance. We designed a schematic diagram with adequate control measures compartmentally which produced the mathematical equations to enable us conduct some analysis regarding the associated dangers in the use of methamphetamine.

Methamphetamine is a potent central nervous system (CNS) stimulant that is mainly used as a recreational drug and less commonly as a second-line treatment for attention deficit hyperactivity disorder and obesity (Borges, Bagge & Orozco, 2016). It is a substance that can be chemically represented as $C_{10}H_{15}N$ whose IUPAC nomenclature is simply named N-methyl-1-phenylpropane-2 amine. It has a melting point of 170^{o}C with a molar mass of 149.2337 g/mol, (Mental Health, 2022; Bridgeman et al., 2017). It is a powerful and highly addictive chemical substanceused illegally as a stimulant and possesses very strong euphoric effects on victims.It is considered to be the second highest illicit drug. It is used as a white,bitter-tasting powder or pill or chunky crystals called ice and nicknamed crystal meth. It is a synthetic stimulant that is addictive and can cause considerable health adversities/ hazards (Cao et al. 2017). It can be swallowed, snorted or injected (Lee, 2022).

The effects of methamphetamine differ from person to person. One can feel exhilarated, aroused, alert, paranoid, confused, aggressive and or disinhibition etc, which vary from one person to the other when the substance is ingested. It can cause increased heart rate and increased blood pressure (Crippa et al., 2010). As against the case of cannabis sativa which enhances appetite and makes you feel either exhilarated, alert, awake, agitated, paranoid, confused, aggressive or rather aroused sexually.

The effect of methamphetamine lasts between 4 hours to 12 hours depending on body make up. Ingesting this substance produces a very intense highness similar to that produced by crack cocaine but it is muchlonger lasting than that of cocaine (MDLLC, 2022). The substance can report positive in a urine test from 1 to 4 days after use in a consumer's body depending onthe quantity consumed by the individual. Apart from its medical use, methamphetamine is NOT good for consumption/ ingestion.

By some groups of researchers, about 1.6 million people use methamphetamine every year and many people out of these number of people suffer addiction to this substance (NIH 2019). Many people suffer methamphetamine disorder. It is evidenced that not every user suffer this stimulant use disorder and addiction.

However, a list of effective treatment approach has been discovered as follows:

Medical detox. Victims may be subjected to complete a medical detox period right after they stop using the substance. Medical detox facilities can help you manage the uncomfortable symptoms of methamphetaminewithdrawal, like cravings, fatigue and body aches (Denson et al 2006). The medical detoxcan also help the victims with mental health symptoms that one might experience like temporary symptoms of depression or psychosis.

Secondly, a behavioral therapy program can be employed as the therapy models are most effective for treating methamphetamine use disorder specifically. A third approach is the matrix model which isspecifically designed to treat stimulant drug addiction including cocaine use disorder. Participants who go through the matrix model program meet in small groups several times a week (Dowshen, 2018). This matrix model consist of three types of interventions such as

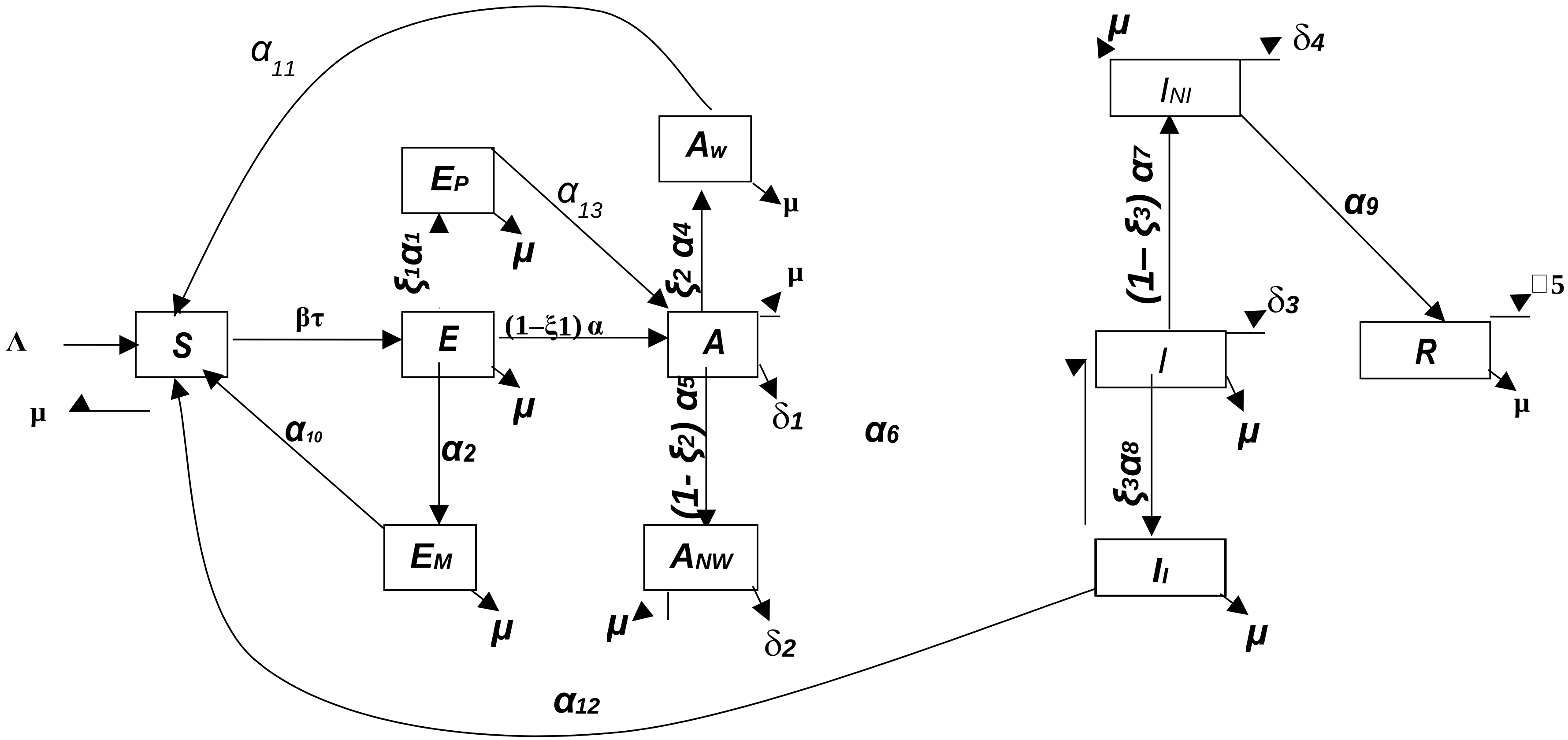
1. Learning about methamphetamine addiction and how it affectsyour body
2. Getting connected to resources in your community and
3. Urine analysis (drug tests)

Research studies have found that stimulant drug users like methamphetamine users who complete the matrix model program,are more likely to stay off drugs. Other approaches include contingency management (CM) etc. *Healthdirect* (2021) suggests that for the fact that methamphetamine contains caffeine, talc and other toxic substances,it is neurotoxic and can damage dopamine and serotonin neurons inthe brain. Its use is also linked to higher frequencies of unprotectedsexual intercourse and violent behavior. Researches also show that its use may lead to structural and functional changes in the brain associated with emotion and memory card, in some cases, these actions may be irreversible.

Commercially, methamphetamine is available under the brand name Deoxyn, in 5-mg tablets. It has a very limited use in the treatment of obesityand attention deficit hyperactivity disorder (ADHD) (Du Plessis et al, 2015). It is also used off-label to treat narcolepsy (Alexander 2009).

Model Formulation

Schematic diagram of methamphetamine consumption



MODEL EQUATIONS DEDUCTED FROM SCHEMATIC DIAGRAM.

1. $\frac{dS}{dt} = \wedge + \alpha_{10}E_M + \alpha_{11}A_W + \alpha_{12}I_I - (\mu + \beta\tau)S$
2. $\frac{dE}{dt} = \beta\tau S - [\xi_1\alpha_1 + \alpha_2 + (1-\xi_1)\alpha_3 + \mu]E$
3. $\frac{dE_M}{dt} = \alpha_2 E - [\mu + \alpha_{10}]E_M$
4. $\frac{dE_P}{dt} = \xi_1\alpha_1 E - [\mu + \alpha_{13}]E_P$
5. $\frac{dA}{dt} = (1-\xi_1)\alpha_3 E + \alpha_{13}E_P - [\mu + \delta_1 + \xi_2 + \alpha_4 + (I-\xi_2)\alpha_5]A$
6. $\frac{dA_W}{dt} = \xi_2\alpha_4 A - [\mu + \alpha_{11}]A_W$
7. $\frac{dA_{NW}}{dt} = (1-\xi_2)\alpha_5 A - [\mu + \delta_2 + \alpha_6]A_{NW}$
8. $\frac{dI}{dt} = \alpha_6 A_{NW} - [\mu + \delta_3 + \xi_3\alpha_8 + (1-\xi_3)\alpha_7]I$
9. $\frac{dI_I}{dt} = \xi_3\alpha_8 I - [\mu + \alpha_{12}]I_I$
10. $\frac{dI_{NI}}{dt} = (I-\xi_3)\alpha_7 I - [\mu + \delta_4 + \alpha_9]I_{NI}$
11. $\frac{dR}{dt} = \alpha_9 I_{NI} - [\mu + \delta_5]R$

Parameter Description:

$\xi1$	=	Discontinue from the use of methamphetamine
$\xi2$	=	Withdraw from group of methamphetamine users.
$\xi3$	=	Isolate and send to consultants for treatment
$\alpha_1, \alpha_2, \ldots, \alpha_{13}$	=	Progression rates
μ	=	Natural mortality rate
$\wedge$	=	Feeds the susceptible class either by birth or by immigration.
$\lambda_1, \lambda_2, \ldots, \lambda_9$	=	Methamphetamine induced deaths
β	=	The interactional force between the susceptible and the exposed class
τ	=	Enlightenment/campaign on the dangers associated with the use of methamphetamine
S	=	Susceptible class
E	=	Exposed class
E_M	=	Exposed as a result of medication
E_P	=	Exposed for pleasurable purposes.
A	=	Addicted class

A_W	=	Addicted but withdrawn from group of users
A_{NW}	=	Addicted but not withdrawn from users
I	=	Insane class
I_I	=	Insane and isolated for treatment
I_{NI}	=	Insane but not isolated for tre
R	=	Removed class
β	=	$\frac{\lambda_1 E + \lambda_2 E_M + \lambda_3 E_P + \lambda_4 A + \lambda_5 A_W + \lambda_6 A_{NW} + \lambda_7 I + \lambda_8 I_I + \lambda_9 I_{NI}}{N}$

Where N = $S + E + E_M + E_P + A + A_W + A_{NW} + I + I_I + I_{NI} + R$.

$\lambda_1, \lambda_2, \ldots, \lambda_9$, = Contact rates in their respective compartments.

Equilibrium State of Methamphetamine Consumption

In a society free from the consumption of methamphetamine, the following condition is obtainable. $E = E_M = E_p = A = A_W = A_{NW} = I = I_I = I_{NI} = 0$.

Clearly $\Lambda \quad -\mu S = 0$

$$\Rightarrow S = \frac{\Lambda}{\mu}$$

Thus $\boldsymbol{E^0} = \left(\frac{\Lambda}{\mu}, \mathbf{0}, \mathbf{0}, \mathbf{0}, \mathbf{0}, \mathbf{0}, \mathbf{0}, \mathbf{0}, \mathbf{0}, \mathbf{0}, \mathbf{0}\right) \in \boldsymbol{R^{11}}$

Stability Analysis of the Equilibrium State of the Society Free From Consumption of Methamphetamine (SFCM)

We can determine the stability of this model if we can examine the modelbehavior near the equilibrium solution supposing there is a possibility tocontrol the use or consumption of the substance methamphetamine in our environment, it is only achievable if the conditions stated below are realistic thus:

$\lambda + \alpha_{10} E_M + \alpha_{11} A_W + \alpha_{12} I_I - (\mu + \beta\tau)S = 0 \beta\tau S - (\xi_1$
$\alpha_1 + \alpha_2 + (1 - \xi_1) \alpha_3 + \mu) E = 0$
$\alpha_2 E - (\mu + \alpha_{10}) E_M = 0$
$\xi_1 \alpha_1 E - (\mu + \alpha_{13}) E_p = 0$

$(1 - \xi_1) \alpha_3 E + \alpha_{13} E_p - (\mu + \delta_1 + \xi_2 \alpha_4 + (1 - \xi_2) \alpha_5) A = 0$
$\xi_2 \alpha_4 A - (\mu + \alpha_{11}) A_W = 0$
$(1 - \xi_2) \alpha_5 A - (\mu + \delta_2 + \alpha_6) A_{NW} = 0$
$\alpha_6 A_{NW} - (\mu + \delta_3 + \xi_3 \alpha_8 + (1 - \xi_3) I = 0 \xi_3 \alpha_8 I -$
$(\mu + \alpha_{12}) I_I = 0$
$(1 - \xi_3) \alpha_7 - (\mu + \delta_4 + \alpha_9) I_{NI} = 0 \alpha_9 I_{NI} -$

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$(\mu + \delta_5) R = 0$

To determine the Eigen-values, we shall resort to Jacobian transforms bylinearizing these systems of equations to obtain the following:

Evaluating the Jacobian Matrix, we shall have the following; $J(f_1, f_2, \ldots, f_{11}) =$

$$\begin{bmatrix}
-M_1 & 0 & \alpha_{10} & 0 & 0 & \alpha_{11} & 0 & 0 & \alpha_{12} & 0 & 0 \\
\beta_\tau & -M_2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & \alpha_2 & -M_3 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & \mathcal{E}_1\alpha_1 & 0 & -M_4 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & (1-\mathcal{E}_1)\alpha_3 & 0 & \alpha_{13} & -M_5 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & \mathcal{E}_2\alpha_4 & -M_6 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & (1-\mathcal{E}_2)\alpha_5 & 0 & -M_7 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & \alpha_6 & -M_8 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \mathcal{E}_3\alpha_8 & -M_9 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & (1-\mathcal{E}_3)\alpha_7 & 0 & -M_{10} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \alpha_9 & -M_{11}
\end{bmatrix}$$

Where $M_1 = (\mu + \beta_\tau)$

$M_2 = (\mu+\alpha_1 + \alpha_2 + (1-\xi_1)\alpha_3)$

$M_3 = (\mu+\alpha_{10})$

$M_4 = (\mu+\alpha_{13})$

$M_5 = (\mu+\delta_1+\xi_2\alpha_4 + (1-\xi_2)\alpha_5)$

$M_6 = (\mu+\alpha_{11})$

$M_7 = (\mu+\xi_2\alpha_6)$

$M_8 = (\mu+\delta_3+\xi_3+\alpha_8 + (1-\xi_3)\alpha_7)$

$M_9 = (\mu+\alpha_{12})$

$M_{10} = (\mu+\delta_4+\alpha_9)$

$M_{11} = (\mu+\delta_5)$

Now, to evaluate the Jacobian Matrix at the free methamphetamine Equilibrium state referred to as SFCM (Society free from consumption of methamphetamine), we shall obtain the following:

In fact, at the SFCM it is of note that $E=E_M = E_P = A = A_W = A_{NW} = I = I_I = I_{NI} = R = 0$.

Of course, there will be no interaction between the users or consumers ofmethamphetamine and the susceptible class, hence the nullity of the interaction force β which has earlier been defined.

This takes us to sourcing for the characteristic equation of the Jacobian Matrix evaluated at the SFCM point.

Thus we compute the usual $|J - \lambda| =$

$$\begin{bmatrix} -M_1\lambda_1 & 0 & \alpha_{10} & 0 & 0 & \alpha_{11} & 0 & 0 & \alpha_{12} & 0 & 0 \\ \beta_\tau & -M_2\lambda_2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & \alpha_2 & -M_3\lambda_3 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & \varepsilon_1\alpha_1 & 0 & -M_4\lambda_4 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & (1-\varepsilon_1)\alpha_3 & 0 & \alpha_{13} & -M_5\lambda_5 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \varepsilon_2\alpha_4 & -M_6\lambda_6 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & (1-\varepsilon_2)\alpha_5 & 0 & -M_7\lambda_6 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & \alpha_6 & -M_8\lambda_8 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & \varepsilon_3\alpha_8 & -M_9\lambda_9 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & (1-\varepsilon_3)\alpha_7 & 0 & -M_{10}\lambda_{10} & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \alpha_9 & -M_{11}\lambda_{11} \end{bmatrix}$$

The characteristic equation of J* is given by

$$F(\lambda_I) = (\lambda_I + M_I)(\lambda_2 + M_2)(\lambda_3 + M_3)(\lambda_4 + M_4)(\lambda_5 + M_5)(\lambda_6 + M_6)(\lambda_7 + M_7)(\lambda_8 + M_8)(\lambda_9 + M_9)(\lambda_{10} + M_{10})(\lambda_{11} + M_{11});$$ where

$\lambda_I = -M_I = -(\mu+\beta_\tau)$ but $\beta = 0$;

Therefore $\lambda_1 = -\mu$

$\lambda_2 = -M_2$

$\lambda_3 = -M_3$

$\lambda_4 = -M_4$

$\lambda_5 = -M_5$

$\lambda_6 = -M_6$

$\lambda_7 = -M_7$

$\lambda_8 = -M_8$

$\lambda_9 = -M_9$

$\lambda_{10} = -M_{10}$

$\lambda_{11} = -M_{11}$

Since the characteristic values are non-positive all through, evidently, it aclear fact that the system is asymptotically stable which ensures the convergence of the solution of this deterministic model.

SENSITIVITY ANALYSIS

Basic Reproduction Number (R_0) of methamphetamine consumption.

We try to study the sensitivity analysis of the parameters of the model by considering the basic reproduction number $R_0 = p(FV^{-1})$. The spectral radius is represented by ρ which is the most-dominant Eigen value of FV^{-1}. R_0 can be thought of as the number of cases one case of methamphetamine consumer generates on average over the course of his consumption period in a given area that is not used to the substance before. This metric is useful because it helps to

determine whether or not a victim of methamphetamine (a consumer) can spread the use of cannabisthrough a given population.
In general, if the individual who become addicted early may be more likelyto introduce the idea of methamphetamine consumption randomly in a given population, then our computation of R_0 must account for this tendency. We will judge this by considering the fact that when $R_0<1$, the contact rate will be very low whereas if $R_0>1$, the contact rate will be veryhigh leading to fast spread of methamphetamine consumption in the population. The higher the value of R_0, the harder it will be to control theescalation of consumers in the identified population. It is established thatwhen $R_0< 1$, then the SFCM is locally asymptotically stable (LAS) and consumers cannot invade the population but if $R_0>1$, the SFCM is unstable and invasion is always possible.

With the basic Reproduction Number R_0 of methamphetamine at the SFCM equilibrium state of this model, it is found that E $(S^0, E^0_M, E^0_P, A^0, A^0_W, A^0_{NW}, I^0, I^0_I, I^0_{NI}, R^0)$

Thus, for us to compute the Reproduction Number R0, the method of nextgeneration matrix G which consist of F and V^{-1} shall apply.

In fact, $F = \left[\frac{\partial f_i}{\partial x_i}\right]$, and $V = \left[\frac{\partial v_i}{\partial x_i}\right]$,

Where F_i are the new consumers into compartments and V_i are the transferof consumers from one compartment to another while Ro is simply the SFCM.

Hence, the following computation follows:
At the SFCM, the Susceptible and are excluded. And we obtain thefollowing for (Fi)'s,
Exposed class (E) = $\beta\tau S$
$E_M = 0$
$E_P = 0$
$A = 0$
$A_W = 0$
$A_{NW} = 0$
$I = 0$
$I_I = 0$
$I_{NI} = 0$

The $(Vj)^{'s}$ are computed as follows:
$E = [\xi_1 \alpha_1 + \alpha_2 + (1-\xi_1) \alpha_3 + \mu]E$
$E_P = \xi_1 \alpha_1 E - (\mu+\alpha_{13}) E_P$
$A = (\mu + \delta_1 + \xi_2\alpha_4 + (1- \xi_2) \alpha 5)$
$A_W = (\mu + \alpha_{11}) A_W$
$A_{NW} = (\mu + \delta_2 + \alpha_6)\ _{ANW}$

$I = (\mu + \delta_3 + \xi_3 \alpha_8 + (1 - \xi 3) \alpha_7) I$
$I_I = (\mu + \alpha_{12}) I_I$
$I_{NI} = (\mu + \delta_4 + \alpha_9) I_{NI}$

Now, at the SFCM, τ is hundred percent effective which implies that τ=1

Hence $\tau S = S = \frac{\wedge\lambda_1}{\mu N} + \frac{\wedge\lambda_2}{\mu N} + \cdots + \frac{\wedge\lambda_9}{\mu N}$

Thus $\beta S = \frac{(\lambda_1 E + \lambda_2 E_M + \lambda_3 E_P + \lambda_4 A + \lambda_5 A_W + \lambda_6 A_{NW} + \lambda_7 I + \lambda_8 I_I + \lambda_9 I_{NI})\frac{\wedge}{\mu}}{N}$

Let $K_1 = K_2 = \cdots K_9 = \frac{\wedge}{\mu N}$ and

We can write

$\beta S\neg = \lambda_1 K_1 + \lambda_2 K_2 +$ ------------- $+ \lambda_9 K_9$

$$F_i = \begin{bmatrix} \beta S \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

$$F = \begin{bmatrix} \lambda_1 k_1 & \lambda_2 k_2 & \lambda_3 k_3 & \lambda_4 k_4 & \lambda_5 k_5 & \lambda_6 k_6 & \lambda_7 k_7 & \lambda_8 k_8 & \lambda_9 k_9 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$\begin{bmatrix} [\xi_1 a_1 a_1 + (1-\xi_1)a_3 + \mu]E \\ a_2 E - [\mu + a_{10}]E_M \\ \xi_1 a_1 E - [\mu a_{13}]E_P \\ [\mu + \delta_1 + (1-\xi_2)a_5]A \\ [\mu + a_{11}]A_W \\ [\mu + \delta_2 + a_6]A_{NW} \\ [\mu + \delta_3 + \xi_3 a_8 + (1-\xi_3)a_7]I \\ [\mu + a_{12}]I_1 \\ [\mu + \delta_4 + a_9]I_{NI} \end{bmatrix}$$

$$V = \begin{bmatrix} \mathrm{M}_2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ a_2 & \mathrm{M}_3 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \xi_3 a_1 & 0 & \mathrm{M}_3 & 0 & 0 & 0 & 0 & 0 & 0 \\ (1-\xi_1)a_1 & 0 & a_{13} & \mathrm{M}_5 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & \xi_2 a_4 & \mathrm{M}_6 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & (1-\xi_2)a_5 & 0 & \mathrm{M}_7 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & a_6 \mathrm{A}_{\mathrm{NW}} & \mathrm{M}_8 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & \xi_1 a_8 & \mathrm{M}_9 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & (1-\xi_{32})a_7 & 0 & \mathrm{M}_{10} \end{bmatrix}$$

RESULTS AND DISCUSSION

We discuss the findings alongside the graphs such that eachobtained graph is discussed immediately just below the graph. We use combinations of the four controls, three controls and two controls at a time. The control measures used include enlightenment/campaign on the dangers associated with the use of methamphetamine, represented by τ,discontinue from the use of methamphetamine (if already started) represented by ξ_1, withdraw from group of methamphetamine users, represented by ξ_2, isolate victim and send him or her to consultants for treatment, represented by $\xi 3$.

This is done under the following scenarios/strategies:

1. Strategy A: $\tau \neq 0$, $\xi_1 \neq 0$, $\xi_2 = \xi_3 = 0$
2. Strategy B: $\tau \neq 0$, $\xi_1 \neq 0$, $\xi_2 \neq \xi_3 = 0$
3. Strategy C: $\tau \neq 0$, $\xi_1 \neq 0$, $\xi_2 \neq \xi_3 \neq 0$
4. Strategy D: $\tau \neq 0$, $\xi_1 \neq 0$, $\xi_2 \neq 0$ $\xi_3 = 0$
5. Strategy E: $\tau \neq 0$, $\xi_3 \neq 0$, $\xi_2 = \xi_1 = 0$
6. Strategy F: $\tau = 0$, $\xi_3 \neq 0$, $\xi_2 \neq 0$, $\xi_3 \neq 0$
7. Strategy G: $\tau = 0$, $\xi_3 = 0$, $\xi_2 \neq 0$, $\xi_1 \neq 0$
8. Strategy H: $\tau = 0$, $\xi_2 = 0$, $\xi_1 \neq 0$, $\xi_3 \neq 0$
9. Strategy I: $\tau = 0$, $\xi_1 = 0$, $\xi_2 \neq \xi_3 \neq 0$

The simulation is done within a period of 4 months study plan bywhich time the discussions from the graphical work is generated.

Parameter values used in the simulation of methamphetamine use.

S/No.	Parameter	Value	Source
1.	Λ	1% of the area under study	Primary and SecondaryData
2.	μ	$\frac{1}{53.6}$	Roger et. al (2009)
3.		0.18	Primary and SecondaryData
4.	τ	$\in[0,1]$	Tivde (2016)
5.	ξ_1, ξ_2, ξ_3	$\in[0,1]$	Primary and Secondary Data
6.	$\alpha_1, \alpha_2 \ldots \alpha_{13}$	$\in[0,1]$	Primary and SecondaryData
7.	δ_1	0.05	Primary and SecondaryData
8.	δ_2	0.06	Primary and SecondaryData
9.	δ_3	0.08	Primary and SecondaryData
10.	δ_4	0.09	Primary and SecondaryData
11.	$\lambda 1, \lambda_2, \ldots \lambda_9$	0.18	Primary and SecondaryData
12.	$K_1, K_2, \ldots K_9$	0.26	Calculated

Graphs Resulting from the Simulation

From Fig 1, the Addicted class shoot up from the onset as a new 'high' brought into the society but gradually came down over time. The 'Exposed'and the 'Addicted but withdrawn' quickly reduced in number when the waveof the effect of methamphetamine started being experienced by users. The other compartments behaved accordingly as the effect or control measures are impacted on them.

From Fig 2, the Addicted class rose very high because of the negative effects associated with the substance whereas the ‘Addicted but withdrawn’ individuals almost remained constant and the ‘Addicted but not withdrawn’ class are very few in number because it poised a great problem for users to withdraw from use.

Fig 3 shows how the Exposed and ‘Exposed for medication’ reduced drastically in number over time while the ‘Exposed for pleasurable purposes’ remained almost constant as they continue to savour the substance continuously.

Fig 4 shows how the ‘Insane but isolated for treatment’ keep increasing in the society with a very slow reduction over time in the given society. The ‘Insane’ and ‘Insane and isolated for treatment’ reduce very drastically inthe society.

Fig 5 shows the interactional behavior of the Recovered, Addicted, Exposedand Insane classes over the period of study.

The graphs of Recovered in Fig 6, Addicted in Fig 7, the Exposed in Fig 8 and the insane in Fig 9 are shown as they behaved over the period under discussion.

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Fig 1.

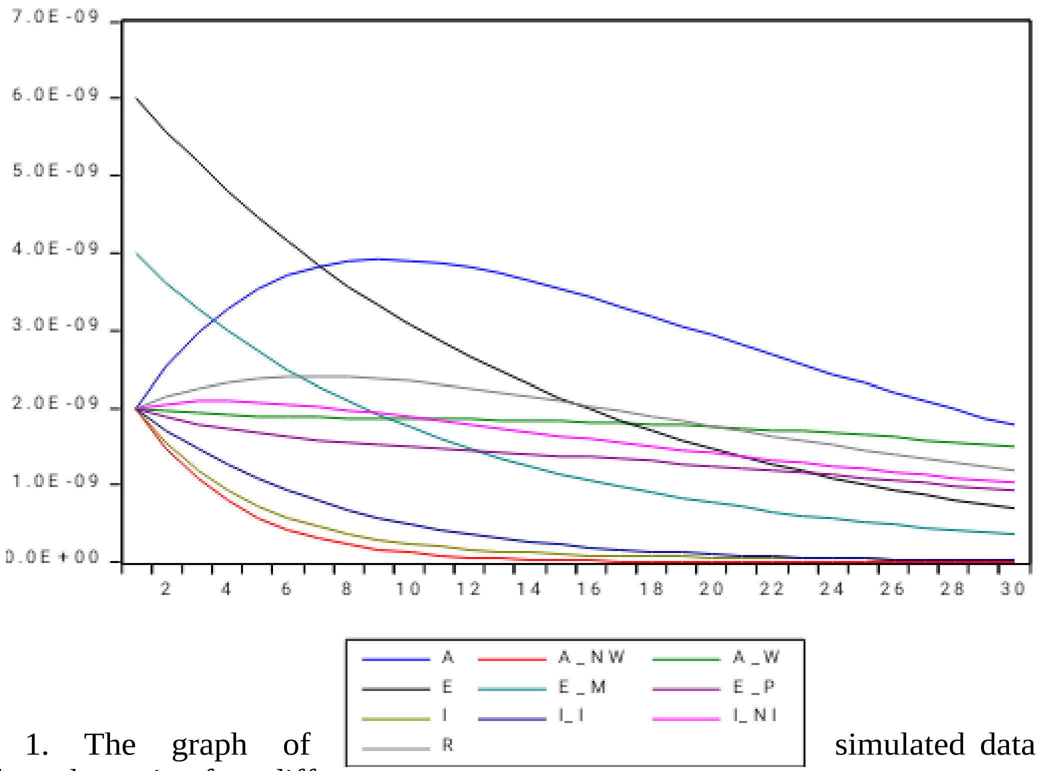


Fig 1. The graph of simulated data on intake of methamphetamine fromdifferent compartments.

A- Addicted class E-Exposed class

I-Insane class

R-Removed class

A_{NW}-Addicted but not withdrawn from users E_M-Exposed as a result of medication.
I_I-Insane and isolated for treatment

A_W-Addicted but withdrawn from groups of usersE_P-Exposed for pleasurable purposes
I_{NI}-Insane but not isolated for treatment.

Fig 2.

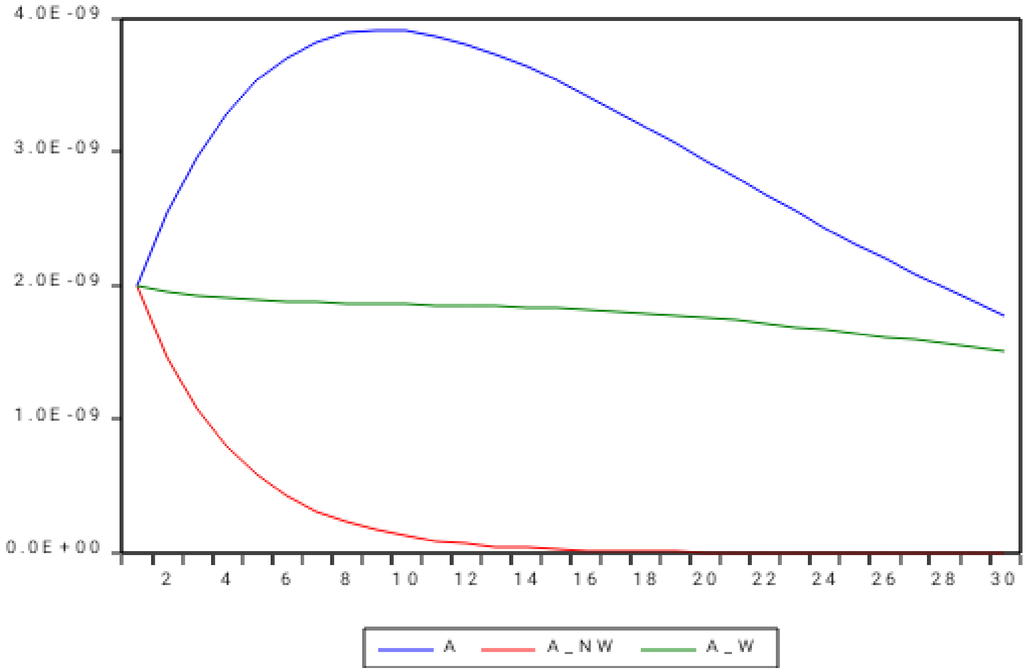


Fig 2. The graph of Simulated data on the Addicted, Addicted but notwithdrawn and Addicted but withdrawn and their behavior over time.

A- Addicted class

A_{NW}-Addicted but not withdrawn from users A_W-Addicted and withdrawn.

Fig 3.

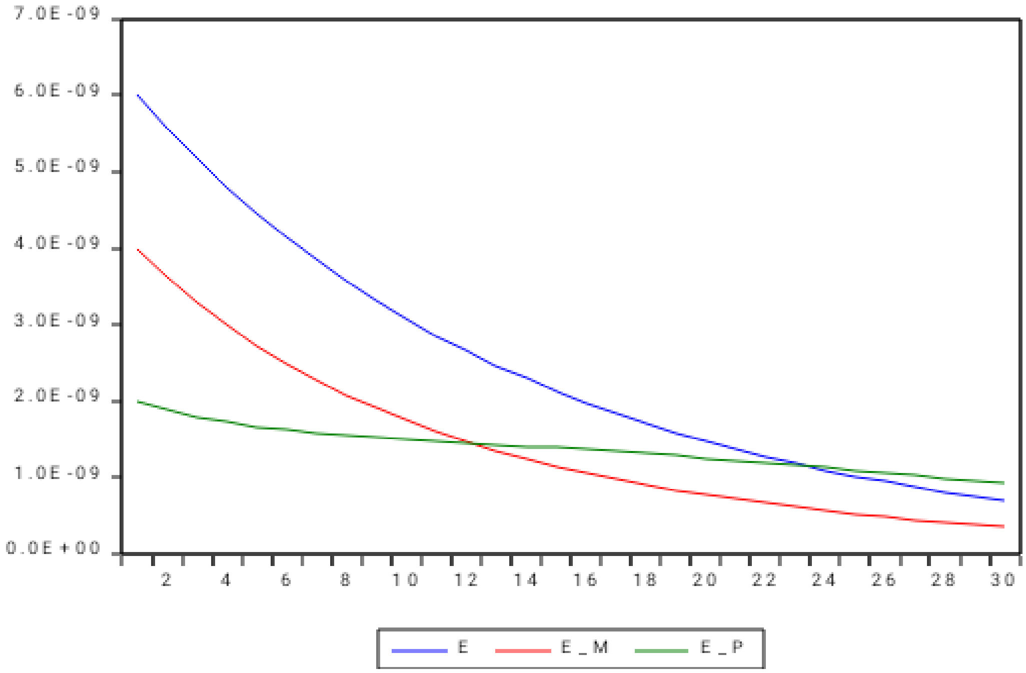


Fig 3. The graph of simulated data on the E-Exposed, E_M-Exposed as a result of medication and E_P-Exposed for pleasurable purposes. The E reduces gradually as a result of harm associated with the use while E_M reduces faster than E because of its potency on users as a result of medications. E_p remained constant because users find so much pleasure inthe methamphetamine.

Fig 4.

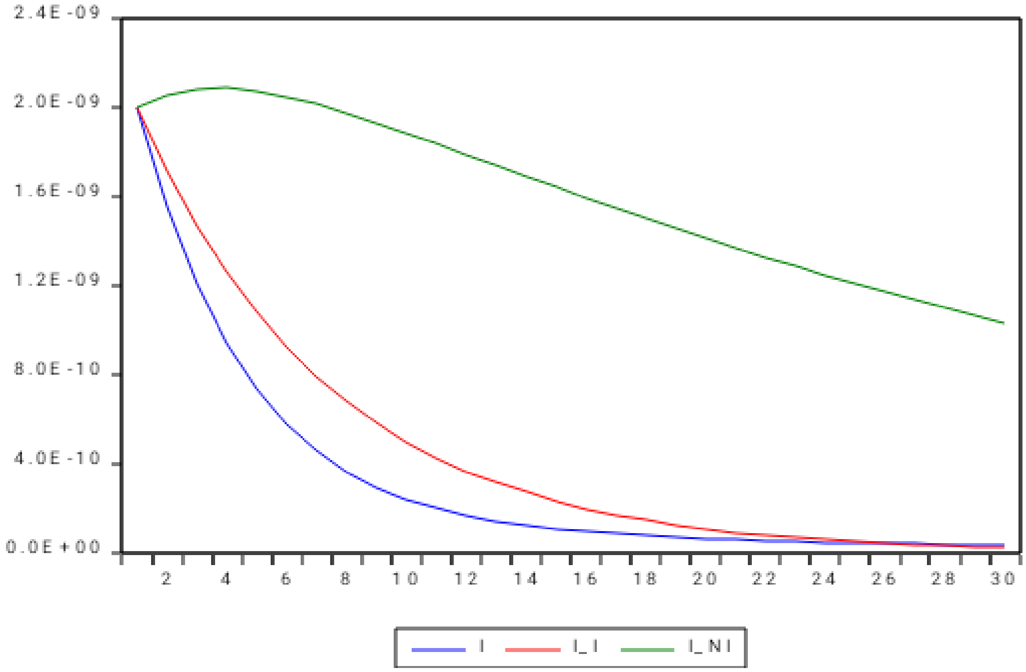


Fig 4. The graph of Simulated data on the I-Insane and isolated for treatment, I_I-Insane and isolated for treatment and I_{NI}-Insane but not isolated for treatment. The I and I_I reduced in number faster as against theI_{NI} who reluctantly reduce in number as consumers.

Fig 5.

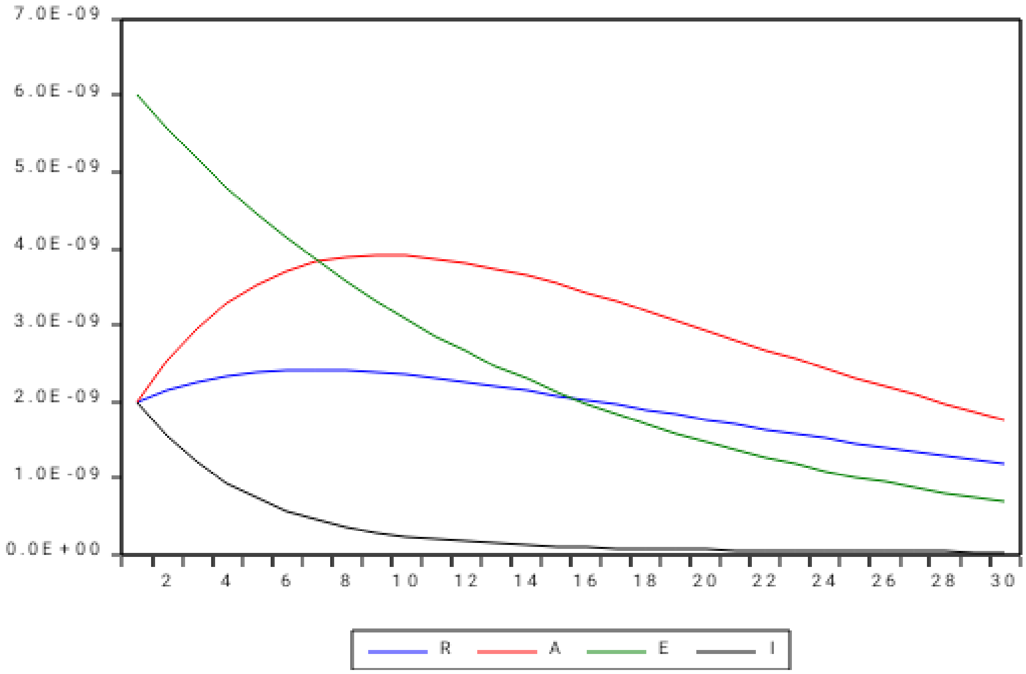


Fig 5. The graph of the Simulated data on the R- Removed, A- Addicted, E-Exposed and I-Insane classes and their interactions over time.

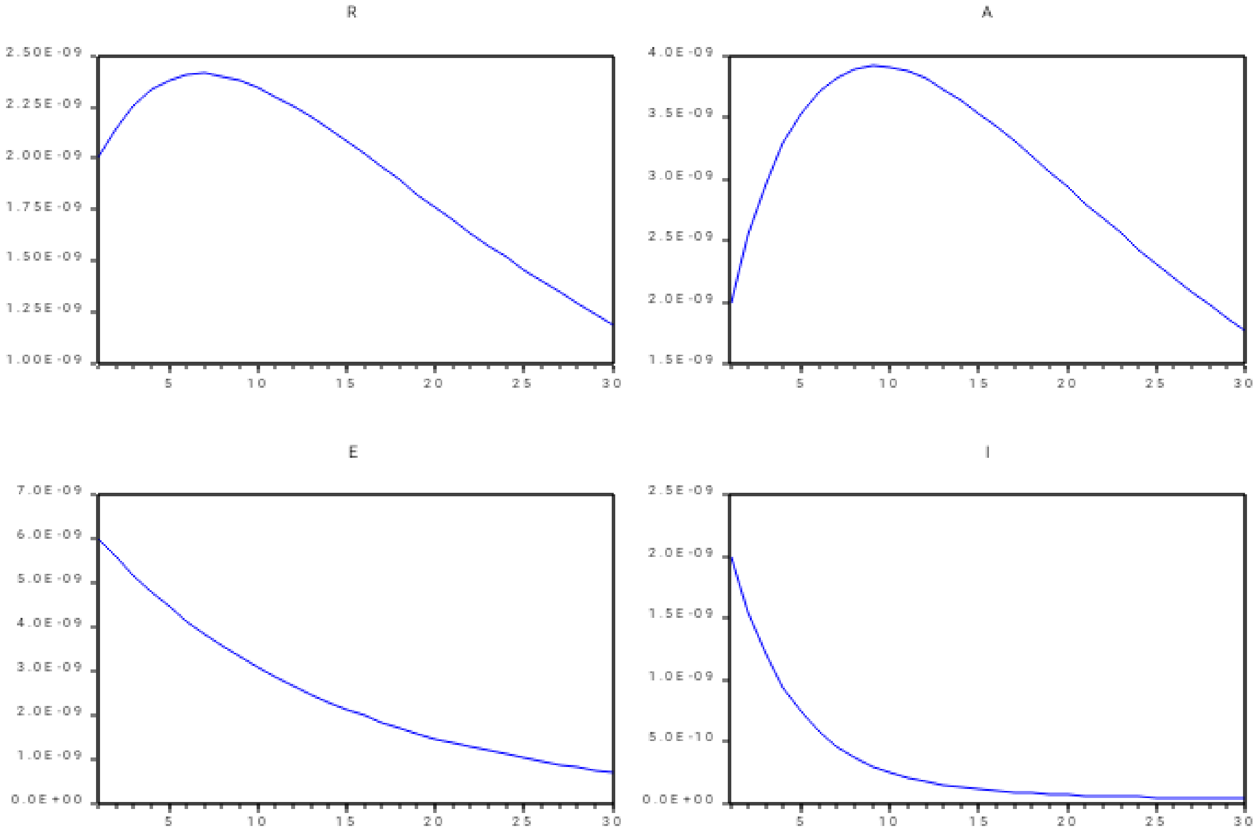
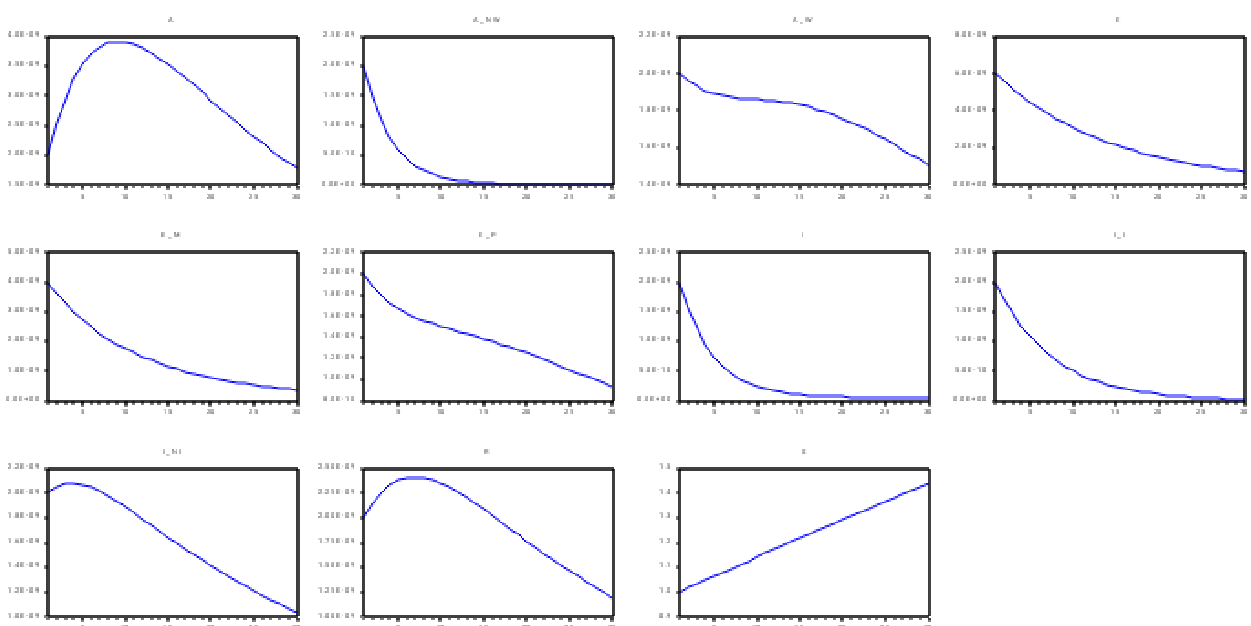


Fig 6, Fig 7, Fig 8 and Fig 9.



The graphs of each respective class and its interactional behavior with respect to the control parameters on the model.

Conclusion:

Our research shows that a good number of methamphetamine users find it difficult to withdraw from the use except for those who use it for purposes of medication. We also discovered that the addicted individuals hardly get well again since the psychoactive nature of the substance is very damaging.Above all, our control parameter denoted by τ which is enlightenment control to avoid use of the substance is most effective. We, therefore, urge the Government to evolve a system whereby the youths are totally withdrawn or not allowed to use methamphetamine.

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