

# The impact of an HIV prevention intervention for injecting drug users in Svetlogorsk, Belarus: model predictions

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Received 11 January 2002; accepted 1 April 2002

## Abstract

**Background:** From the mid-1990s there has been a rapid spread of HIV infection amongst injecting drug users (IDUs) in Svetlogorsk, Belarus. In 1997, when the IDU HIV prevalence had reached 74%, two needle and syringe exchange points (NEPs) were established in the town. These interventions have been operating since then, with some interruptions due to a lack of funding 1998. **Methods:** This article presents a deterministic epidemiological model 'IDU 2.4' that simulates the transmission of HIV among IDUs sharing injecting equipment, and between IDUs and their sexual partners. The model incorporates the impact of the interrupted distribution of clean syringes and condoms, is validated against data from Svetlogorsk, and is used to estimate the impact of the intervention on HIV transmission. **Results:** The model predicts that between 1997 and 2000 the intervention averted 414 HIV infections in Svetlogorsk (95% CI, 180–690) and caused a 6.5% decrease in IDU HIV prevalence compared to if there had been no intervention. The analysis also suggests that the gap in funding between 1998 and 1999 resulted in a 35% reduction in the number of HIV infections averted among IDUs during that period, and that the IDU HIV prevalence is 3% higher in 2000 (95% CI, 1.9–4.6%) than if there had been no gap in funding. **Conclusions:** Even though the HIV prevalence and incidence amongst the IDUs remained high, the findings suggest that the intervention had an important affect on HIV transmission in Svetlogorsk, Belarus. The findings reinforce the importance of strengthening existing projects and replicating similar projects in the region, and highlight the detrimental impact of gaps in intervention funding.

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**Keywords:** Injection drug users; HIV; Belarus; Mathematical models; Effectiveness; Interventions

## Introduction

The rapid spread of HIV infection among injecting drug users (IDUs) has been documented in a large number of countries in Central and Eastern Europe, Asia and North America (Des Jarlais et al., 1998; Rhodes et al., 1999; Stimson & Choopanya, 1998; Strathdee et al., 1998). The main factor associated with transmission is the multi-person re-use or sharing of syringes and needles (Brogly et al., 2000). In addition, the indirect sharing of equipment such as water, cotton, cookers and other drug preparation equipment has been attributed to assisting HIV transmission (McCoy et al., 1998). Particularly where IDUs sell sex to help fund their drug

use, IDUs are also vulnerable to HIV infection through sexual transmission. They are also at high risk from other blood-borne infections such as hepatitis B and C, and from premature death from drug overdose or sepsis infection (Donoghoe & Wodak, 1998; Goedert et al., 2001).

HIV prevention activities focused on IDUs often adopt a range of strategies to reduce the risk of HIV infection through both injecting drug use and unsafe sex. A comprehensive strategy for HIV prevention among IDUs may include the primary prevention of drug abuse, the provision of information, education and counselling to reduce syringe sharing, use of bleach to disinfect syringes and drug preparation equipment, changing laws to permit legal purchase of needles or syringes, outreach using peer educators, the provision of clean needles and syringes, and the collection and disposal of used injecting equipment, referral for treat-

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ment of medical problems such as STIs, and access to substance abuse treatment (Des Jarlais et al., 2000; Jones & Vlahov, 1998; McCoy et al., 1998; Sears et al., 2001). These are often complemented by activities to address the other health and welfare needs of IDUs.

There is some evidence that if HIV transmission among IDUs can be prevented or slowed, then this will influence the wider transmission of infection (Ball et al., 1998). Yet, despite their potential effect, in many regions of the world promoting and supporting interventions working with IDUs is highly sensitive. Politicians may be concerned about providing services to individuals who engage in illegal acts, for example. Other agencies may feel that resources for HIV prevention may be better invested elsewhere. Proponents argue that IDU interventions have a range of benefits, will have a broad influence on the HIV epidemic, and are cost-effective. Towards this end, epidemiological research, mathematical modelling and economic analysis have been used to estimate the impact of IDU interventions in different settings, and its associated cost-effectiveness. For example, in the US, models estimating the impact and cost-effectiveness of promoting access to sterile syringes suggest that such interventions can have a significant impact (Kaplan & O'Keefe, 1993) and are relatively cost-effective, especially when compared to the life-time cost of HIV treatment (Holtgrave et al., 1998; Jacobs et al., 1999; Laufer, 2001; Lurie et al., 1998).

However, a major challenge associated with estimating the impact or cost-effectiveness of IDU interventions are the difficulties associated with estimating how an intervention may have altered patterns of HIV transmission. This is because, by averting one HIV infection of an IDU, a subsequent chain of HIV infections among the needle sharing and sexual partners of the IDU may be averted. In practice interventions are primarily able to collect process data (such as the number of syringes and needles distributed) and outcome data (such as the extent of reported behaviour change). Even when information about the temporal trends of HIV infection among IDUs is available (for example, Des Jarlais et al., 2000; van Ameijden & Coutinho, 1998; Vanichseni et al., 2001), without a control group it is difficult to estimate how this may have differed if there had been no intervention. It is also difficult to quantify the benefits to the sexual partners of IDUs. Mathematical modelling can be used to provide insights into these issues (Bogard & Kuntz, 2002; Holtgrave et al., 1998).

This article presents the model structure and underlying mathematics for an epidemiological model 'IDU 2.4', which was developed in consultation with an IDU intervention in Svetlogorsk, Belarus. We describe here how the model was used to estimate the impact on HIV transmission of the Svetlogorsk intervention, present the results of a detailed uncertainty analysis, and compare the model projections with the intervention data.

## Overview of the HIV epidemic and IDU intervention in Svetlogorsk, Belarus

Until the mid-1990s most of the countries of Eastern Europe appeared to have been spared the worst of the HIV/AIDS epidemic. In 1994, UNAIDS estimated that the whole of Eastern Europe had about 30 000 infections, 15 times fewer infections than Western Europe, and 400 times fewer than in sub-Saharan Africa (UNAIDS, 1998). However, since then the region has seen a 30-fold increase in infections, by the end of 2000, it was estimated that 1 000 000 people were infected (UNAIDS, 2001). In the region, the predominant mode of HIV transmission is through the injection of drugs. At present Ukraine, Belarus and Russia are the worst affected countries with Ukraine having an adult HIV prevalence of 1% (UNAIDS, 2001). However, Moldova, Estonia, Kazakhstan, Kyrgyzstan, Tajikistan, Uzbekistan have all registered large increases in recent years.

Svetlogorsk is a small town of population 75 000 in the Gomel region in the south west of Belarus. It was created in the mid-1960s to supply the two main industries in the area, the power station and the chemical works. The first HIV-infected person was diagnosed in Belarus in 1987. The HIV prevalence remained very low until 1996, but thereafter has been increasing rapidly (Rhodes et al., 1999). In September 1998, 2173 HIV-infected individuals were recorded in Svetlogorsk, with an estimated 83% of infections resulting from unsafe injecting drug use, and 15% infected through sexual transmission (Lakhumalani et al., 1998). The National AIDS Prevention Centre (NAPC) stated that each administrative region in Belarus had reported HIV infections, with 81% of all HIV infections in the Gomel region (Lakhumalani et al., 1998). This is due to high levels of injecting drug use among young people (Lakhumalani et al., 1998), particularly in Svetlogorsk (unpublished Svetlogorsk project data collected by Vladimir Romantsov, 1999).

In January 1997 a pilot prevention project focused upon IDUs was initiated in Svetlogorsk by UNAIDS and the non-governmental organisation (NGO) 'Parents for the future of Children'. Because of the rapid spread of HIV amongst the IDUs in Svetlogorsk, health workers and the militia in Svetlogorsk were already searching out and registering IDUs at the narcology centre. At the start of the intervention in 1997 there were 411 male and 137 female registered IDUs, with the majority aged between 19 and 29. Following an initial assessment and behavioural research, two needle and syringe exchange points (NEPs) were established in March and June 1997 in the two suburbs of Svetlogorsk with the highest concentration of IDUs. The main objectives of the intervention were to: (a) Inform and educate the town population and IDUs about the risks of injecting drug use, and the safe use of syringes and

needles (using the local press and TV station and by distributing leaflets and posters); (b) reduce the risk of HIV infection from the re-use of syringes and/or needles (through the distribution of disinfectants and clean needles and syringes, and the collection and incineration of used needles and syringes at NEPs); (c) reduce the risk of HIV transmission through sexual contact (through the distribution of condoms at NEPs, safer sex education and condom provision by peer educators, and the referral of IDUs to a specialised STI clinic at the local hospital where necessary); (d) provide psychological counselling and legal support where required.

From 1997 to 1999 the project had 44 541 visits by IDUs and distributed 150 539 syringes and 44 509 condoms (unpublished Svetlogorsk project data collected by Vladimir Romantsov, 1999 and personal communication, Roman Gailevich, UNAIDS, 2000). The breakdown of these data by year is shown in Table 1.

In 1997 and 1999, the project distributed more syringes and condoms than in 1998. This is because between August 1998 and March 1999 the project had lower levels of funding than at other times. This lack of funding resulted in the project distributing approximately one-quarter the number of syringes and three-quarters the number of condoms per month in 1998 as compared to 1997 and 1999.

Two main behavioural surveys of the IDUs in Svetlogorsk have been conducted. The first was in January 1997, before the start of the intervention and the second was in May 1999. Key findings are summarised in Table 2. For logistical reasons, the two surveys did not seek to involve the same cohort of IDUs, or follow the same sampling procedure. The first survey was conducted before NEP had started, and so IDUs were identified at key points in the town. In the second survey most IDUs interviewed were identified at the two NEPs. This will have biased the sample towards IDUs having contact with the intervention. As these IDUs may be likely to give answers that are socially acceptable this could result in an over-reporting of different protective behaviours. However, there is some evidence from other settings that NEP attenders are frequently at higher risk than other IDUs (Brogly et al., 2000; Monterroso et al., 2000; Schechter et al., 1999), so it is also possible that the reported behaviour underestimates

Table 1  
Number of visits to the NEPs and the number of syringes and condoms distributed

NEP output indicator	1997	1998	1999
Number of visits	10 203	18 915	15 423
Number of syringes distributed	72 000	16 700	61 839
Number of condoms distributed	16 000	11 600	16 909

Table 2  
Key behaviours reported by IDUs from Svetlogorsk in 1997 and 1999

IDU reported behaviour	1997 ( <i>n</i> = 200)	1999 ( <i>n</i> = 110)
Average duration IDUs have been injecting drugs	NA	6.5 years
Percentage ever shared syringes	92%	35% <sup>a</sup>
Average duration of use of syringes before disposal	2.26 days	1.78 days <sup>b</sup>
Percentage never clean syringes before re-use	84%	45% <sup>a</sup>
Percentage injecting for less than 1 year	13%	5% <sup>b</sup>
Percentage of sex partners that are non-IDUs	37%	56% <sup>a</sup>
Percentage that report never using condoms	71%	37% <sup>a</sup>
Percentage that have more than 1–2 sex partners per week	29%	25%

<sup>a</sup> *P* < 0.01.

<sup>b</sup> *P* < 0.05.

the true intervention effect, as has been reported in a study of an NEP project in Baltimore, MD (Safaeian et al., 2002). Because of these sampling difficulties and the lack of a control group, the data collected should be treated with caution, but do suggest that there was some degree of behaviour change amongst the IDUs (Table 2).

In Svetlogorsk data on the HIV prevalence among the IDU population has been collected in two ways: (1) by testing the HIV prevalence of registered IDUs (1997, 1999 and 2000) and (2) by assessing HIV prevalence among syringes returned to the NEP (October 1997 and April 2000). Among the IDUs tested, the HIV prevalence was 74% in 1997 (*n* = 1296), before the start of the intervention, 75% in 1999 (*n* = 548) after 2 years of intervention activity and 71% in 2000 (*n* = 577). In contrast, the HIV prevalence among the syringes returned to the NEP was 67% in October 1997 (*n* = 202) and 66% in April 2000 (*n* = 250). The estimates obtained from each method are consistently different, with the HIV prevalence of the registered IDUs being 5–7% higher than the HIV prevalence of the syringes. The reason for the marked difference between the registered IDU population and syringe HIV prevalence estimates is unclear. However, it has been suggested that once a needle exchange program has been initiated, the HIV prevalence of returned syringes will underestimate the HIV prevalence in an IDU population (Kaplan & O'Keefe, 1993). This could be the case in Svetlogorsk, where both syringe HIV prevalence estimates were obtained more than 6 months after the initiation of the needle exchange program. For this reason, we use the HIV prevalence estimates from the registered IDUs to parameterise and validate our model.

All HIV-negative registered IDUs in Svetlogorsk are tested for HIV each year. Table 3 presents data on the

percentage of registered IDUs who tested HIV-positive each year. This includes the registered IDUs who have been infected since their last test and newly registered IDUs who are HIV-positive. If the newly registered IDUs have been injecting for a short period of time or if there are few newly registered IDUs, then this data can be used as an approximate measure for the IDU HIV incidence. In practice the high percentage of registered IDUs testing HIV-positive in 1996 and 1997 is probably due to a large proportion of the IDUs who tested positive having been infected in previous years (project staff stated that a large number of IDUs were newly registered in 1996 and 1997). Few IDUs were newly registered and tested in 1998 and 1999, and so the figures for these years are probably a fair estimate of HIV incidence. The large decrease in the percentage of IDUs testing HIV-positive from 1997 to 1998 also suggests that there may have been a decrease in the proportion of HIV-susceptible IDUs who became infected each year, although this cannot be confirmed.

## Methods

### Model development

The focus of *IDU 2.4* was to develop a model that could be used by non-mathematicians to estimate the impact of HIV prevention activities among IDUs in different settings. A draft framework for the model was developed following a review of literature on current transmission models and IDU interventions, and consultation with a joint UNAIDS and WHO advisory committee. During two visits to Svetlogorsk discussions were held with project staff to learn about the intervention, and its associated outcomes. Project reports were reviewed, and existing IDU behavioural, epidemiological, and intervention-specific data were compiled. The model framework was then revised to reflect the forms of data being collected, and the patterns of sexual and injecting behaviour being documented. The model was designed to produce estimates of the number of HIV

#### Box 1. Differential equations for IDU 2.4 HIV transmission equation

$$\frac{dx_{rij}}{dt} = n_{rij}\Lambda_r - x_{rij}(\pi_{idu} + \pi_{sex} + \psi_r + \sigma_r),$$

$$\frac{dh_{rij}}{dt} = x_{rij}(\pi_{idu} + \pi_{sex}) - h_{rij}(\psi_r + \sigma_r + \nu),$$

$$\frac{dy_{rij}}{dx} = \nu h_{rij} - y_{rij}(\psi_r + \sigma_r + \delta)$$

The population of 'n' IDUs are divided into those who are susceptible to HIV infection ( $x$ ), those that are recently HIV infected and in the initial high-viraemia phase ( $h$ ), and those who have progressed into the low-viraemia phase ( $y$ ). The subscripts  $r$ ,  $i$  and  $j$  denote the sex, injecting behaviour and sexual activity (including level of condom use) of the IDUs, respectively. New IDUs enter the susceptible population at a fixed per-capita recruitment rate ( $\Lambda_r$ ). Susceptible IDUs become infected with HIV at a per-capita rate which is determined by the risk associated with sharing needles or syringes with other IDUs ( $\pi_{idu}$ ), and the per-capita risk associated with their sexual behaviour with IDUs and/or non-IDUs ( $\pi_{sex}$ ). When a susceptible IDU becomes infected with HIV he/she is initially highly infectious (for an average period  $1/\nu$ ). They then enter a long period of low infectivity (average duration  $1/\delta$ ). In the model IDUs remain in the population until they stop injecting drugs (IDUs inject for an average period  $1/\sigma_r$ ), or until they cease sharing needles due to chronic HIV-related illness (average duration  $1/\delta$ ), or until they die from a sepsis infection or a drug overdose (at a rate  $\psi_r$ ).

#### STI transmission equation

$$\frac{dx_{rij}^s}{dt} = n_{rij}\Lambda_r - x_{rij}^s \left( \pi_s + \psi_r + \sigma_r + \frac{\delta y_{rij}^s}{n_{rij}} \right) + \mu_r y_{rij}^s,$$

$$\frac{dy_{rij}^s}{dt} = x_{rij}^s \pi_s - y_{rij}^s \left( \mu_r + \psi_r + \sigma_r + \frac{\delta y_{rij}^s}{n_{rij}} \right)$$

The parameter  $x^s$  denotes the number of IDUs susceptible to STI infection, and  $y^s$  the number infected with an STI. Susceptible IDUs become infected with STI at a per-capita rate which is determined by the risk associated with their sexual behaviour with IDUs ( $\pi_s$ ). When a susceptible IDU becomes infected with STI they remain infected for a fixed period of time ( $1/\mu_r$ ), and then become susceptible to STI infection once more.

Table 3  
Number of registered susceptible IDUs and newly registered IDUs tested and testing HIV-positive between January 1996 and March 1999

	1996	1997	1998	3 months 1999
IDUs tested	1101	638	317	72
IDUs testing HIV-positive	658	298	51	11
Percentage testing HIV-positive	60%	47%	16%	15%

infections averted over different time spans. The model complements a *Costing Guidelines For HIV/AIDS Prevention Strategies Among Injecting Drug User Populations* that has been developed to provide a basis for a standardised approach to the collection of cost data from IDU interventions (Kumaranayake et al., 1999).

*Model structure*

IDU 2.4 is a deterministic mathematical model that simulates the transmission of HIV and an STI over time, resulting from syringe and needle sharing between IDUs, and heterosexual contacts between male and female IDUs and with non-IDU sexual partners. The basic structure of the model is shown in Fig. 1. The two main transmission equations of the model and the parameter definitions are shown in Box 1.

A full mathematical description of the model can be obtained from the authors. The model is formulated as a set of deterministic ordinary differential equations that describe the movement of IDUs between discrete sub-populations—based upon their sex, injecting and sexual behaviour, and HIV infection status. Males and females

are each divided into three needle sharing activity classes (none, low and high levels of sharing) and three sexual activity classes (none, low and high numbers of sexual partners per month). The ‘high sexually active’ class of IDUs is further divided into three condom use classes according to their consistency of condom use (none of the time, some of the time, all of the time). The low sexually active IDUs are assigned an average consistency of condom use. The model assumes that IDUs from different sexual activity and needle sharing activity classes mix assortatively to form needle sharing and sexual partnerships. Input parameters are used to describe the extent to which male and female IDUs form sexual partnerships with IDUs and with non-IDUs

A generic STI is included in the model. When a susceptible individual becomes infected with an STI they remain infected for an average duration before recovering and becoming susceptible again. When a susceptible IDU or non-IDU becomes infected with HIV they first enter a short period of high viraemia which is then followed by a much longer period of low viraemia prior to acquiring AIDS and leaving the population due to severe morbidity. It is assumed that the infectiousness of an IDU is increased by five- to 30-fold if they have high viraemia, and that the presence of STI infection in either partner in an HIV discordant sexual partnership increases the per-sex-act probability of HIV transmission by five- to 25-fold.

In the model, a susceptible IDU can become infected with HIV through either having unprotected sex or sharing a needle or syringe with an infected individual. It is assumed that the likelihood of this happening per partnership is dependent on the number of needle

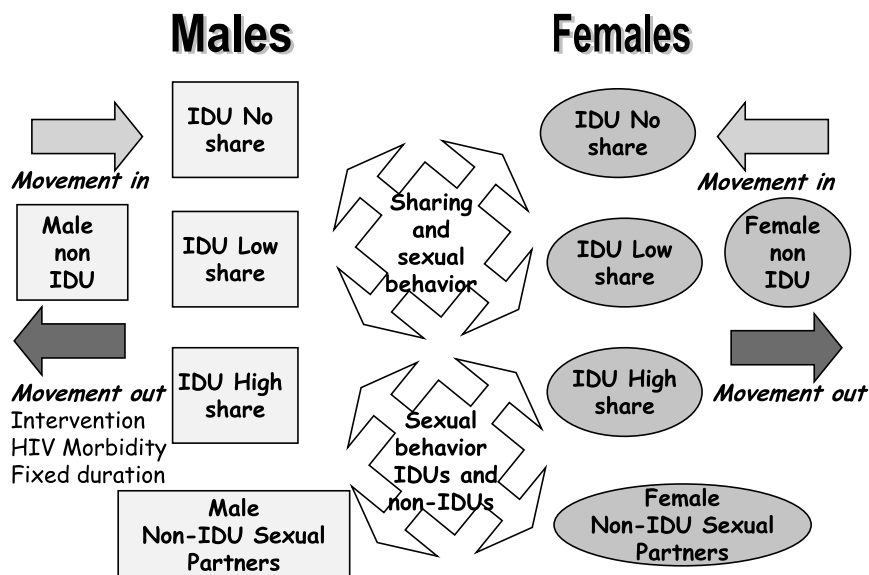


Fig. 1. Outline of structure of IDU 2.4.

sharing or unprotected sexual acts they have, whether either partner has an STI or whether the infected partner has high viraemia. Cleaning used syringes or needles before re-use and using a condom reduces the per-act probability of infection by a fixed amount (10–40% for cleaning and 60–90% for condoms). The probabilities of HIV transmission between a susceptible and infected individual per unit time are derived from Weinstein et al. (1989). The probability that a susceptible IDU becomes HIV infected per unit time from needle sharing ( $\pi_{\text{idu}}$ ) or unprotected sex ( $\pi_{\text{sex}}$ ) is 1 minus the probability of not getting infected over this time. This in turn is the product of the probabilities of not being HIV infected from any of their needle sharing partners or sexual partners from each behavioural subgroup. The non-IDU sexual partners of an IDU are infected in the same way. The probability that a susceptible IDU becomes HIV infected from an infected needle sharing or sexual partner per unit time is given in Box 2.

For a given setting the model is parameterised using context-specific epidemiological, behavioural and intervention-specific inputs. Using data on the risk behaviour of the IDUs before and after the intervention, the model is run twice to simulate the patterns of HIV transmission with and without the intervention. By comparing the output of the two simulations, the model can estimate

the impact of the changes in risk behaviour that have occurred during the intervention. The cumulative number of HIV infections averted over a specific timeframe is taken to be the difference between the projected number of HIV infections that would have occurred with and without the intervention over that time period. Although the model focuses primarily on describing the patterns of HIV transmission among IDUs, it also estimates the impact of the intervention on the non-IDU sexual partners of IDUs.

Many NGOs have difficulty obtaining long-term funding, and often finance ongoing HIV prevention activities by piecing together several short-term grants. A common problem with this is gaps in funding, which then may disrupt the implementation of prevention activities. The model estimates the effect of these periods of reduced intervention activity by allowing the user to specify time intervals where there were gaps in funding. During these periods the model assumes that some patterns of risk behaviour of the IDUs return partially to their pre-intervention levels (as was observed after the closure of an NEP in Connecticut, Broadhead et al., 1999). In particular, as condom use and the reduced sharing of syringes and needles are dependent upon their recurrent supply, the model assumes that a disruption in funding reduces the levels of condom use and increases the levels of needle sharing.

### Box 2: Probability that a susceptible IDU becomes HIV infected from a needle sharing or sexual partner

#### Probability that a susceptible IDU becomes HIV infected from an infected sexual partner per unit time ( $P_{\text{sex}}$ )

$$P_{\text{sex}} = 1 - [1 - \beta_{\text{sex}}(1 - fe)]^n$$

The probability that the susceptible IDU becomes HIV infected in ‘ $n$ ’ sex acts with an HIV-infected partner is 1 minus the probability that they remain uninfected in all ‘ $n$ ’ sexual acts they have with the infected IDU. If condoms are used with consistency ‘ $f$ ’ then there is a probability ‘ $e$ ’ that the susceptible IDU will be protected from infection, and a probability  $[1 - \beta_{\text{sex}}(1 - ef)]$  that the IDU was not HIV infected in one sex act, where  $\beta_{\text{sex}}$  is the probability of HIV transmission per sexual act. The probability that IDU remains uninfected in ‘ $n$ ’ acts is  $[1 - \beta_{\text{sex}}(1 - ef)]^n$ . The equation can be further extended to incorporate the role of high viraemia or STIs (both increase the per-sex-act probability of HIV transmission). An analogous equation is used to describe the probability that a susceptible IDU becomes infected with an STI.

#### Probability that a susceptible IDU becomes HIV infected from an infected needle sharing partner per unit time ( $P_{\text{idu}}$ )

$$P_{\text{idu}} = 1 - [1 - \beta_{\text{idu}}(1 - bc)]^m$$

The probability that a susceptible IDU becomes HIV infected from an infected IDU in ‘ $m$ ’ sharing incidents is 1 minus the probability of them remaining uninfected in all of the ‘ $m$ ’ needle sharing incidents they have with the infected IDU. If the needle and/or syringe is cleaned prior to each sharing incident (with consistency ‘ $b$ ’) then there is a probability ‘ $c$ ’ that the syringe will be disinfected. The susceptible IDU will be protected from infection with probability  $[1 - \beta_{\text{idu}}(1 - bc)]$ , where  $\beta_{\text{idu}}$  is the probability of HIV transmission per needle sharing incident. The probability that IDU remains uninfected in ‘ $m$ ’ sharing incidents is  $[1 - \beta_{\text{idu}}(1 - bc)]^m$ . The equation can be further extended to incorporate the role of high viraemia (assumed to increase the sharing probability of HIV transmission).

### *Model inputs*

The model requires a range of epidemiological, behavioural, demographic and intervention-specific parameters. The full set of model inputs used in the calculations is given in [Appendix A](#). The epidemiological inputs required include the initial HIV prevalence among IDUs at the start of the intervention, the male-to-female and female-to-male HIV and STI transmission probabilities per-sex-act, the average duration of high viraemia and STI infection, and the extent to which the presence of an STI facilitates HIV transmission. The HIV prevalence data were estimated from Svetlogorsk project data. All other data were taken from the scientific literature, and reflect current understanding about HIV and STI transmission.

The behavioural parameters were estimated from the survey data collected in Svetlogorsk in January 1997 and May 1999 ([Table 2](#)). The data from January 1997 were used to estimate the pre-intervention patterns of sexual and injecting behaviour. The data from May 1999 were used to estimate the impact of the intervention on the injecting and sexual behaviour among IDUs having contact with the intervention.

The demographic inputs required included the size of the male and female IDU population, the rate of movement of new IDUs into the injecting population, and mortality rates among HIV infected and non-infected IDUs. These were estimated using project records, data collected during the 1997 and 1999 behavioural surveys, and following consultations with health service providers in Svetlogorsk.

An estimate of the relative reduction in the use of condoms and clean needles and syringes during the period of reduced intervention activity was obtained by comparing the number of condoms and needles and syringes distributed between January 1998 and March 1999 with the numbers distributed from March to December 1997. From this we estimated that during the period of reduced funding the levels of condom distribution were reduced by 25%, and the levels of needle and syringe distribution were reduced by 75%. Consequently, we assume that during this period IDUs reached by the intervention reduced their levels of condom use by 25%, and increased their levels of needle sharing by 75% of the difference between the 1997 and 1999 self-reported levels of needle sharing.

Estimates of the number of IDUs who are regularly in contact with the intervention were estimated from project records of the number of IDUs attending NEPs, and the estimate of the overall size of the IDU population.

### *Estimating intervention impact and handling uncertainty in data inputs*

*IDU 2.4* was designed to estimate the impact of the intervention in Svetlogorsk. However, obtaining estimates of intervention impact is complicated by the different forms of uncertainty associated with many of the model inputs ([Table 4](#)). These relate both specifically to the behavioural, epidemiological and intervention data from the Svetlogorsk intervention, and more generally to scientific uncertainty regarding the per-sex-act probability of HIV transmission in the presence and absence of STI co-infection, and HIV high viraemia, and the risk of HIV transmission if an infected needle or syringe is used by a susceptible IDU.

Because of this uncertainty, it is difficult to choose one unique set of parameter values to describe the Svetlogorsk intervention. One option is to select the model parameter set that best fits the model projections to output data. However, as the model has a large number of input parameters it is possible to find more than one set of inputs that closely fit the model to the epidemiological and project data from Svetlogorsk. Consequently, we undertook a detailed uncertainty analysis of the model ([Blower & Dowlatabadi, 1994](#)) to both validate the model against epidemiological data from Svetlogorsk and to estimate the number of HIV infections averted by the intervention between 1997 and 1999. This analysis aims to assess how the uncertainty in the input data affects the overall impact estimates. To do this, for each model input we developed a probability distribution of the potential range of values that it could take ([Appendix A](#)). Where possible, the range was based on the data collected in Svetlogorsk. For STI and high HIV viraemia cofactors for HIV transmission the ranges commonly presented in other analyses were used ([Korenromp et al., 2000](#); [Seitz & Mueller, 1994](#); [Sweat et al., 2000](#)). Where it was not possible to identify from the data or literature the appropriate distribution of a parameter, a uniform or triangular distribution was used: a triangular distribution was used when a certain parameter estimate was more likely than the others, and a uniform distribution was used otherwise.

For each uncertainty analysis Latin Hypercube sampling was used to generate 500 sets of input parameters ([Blower & Dowlatabadi, 1994](#)). This entailed dividing the cumulative probability distribution for each parameter into 500 equal intervals. Each of the 500 input parameter sets was obtained by randomly selecting without replacement an interval from each parameter distribution, and then randomly selecting a parameter value from within the selected interval. This method of sampling was used in preference to other methods because it offers increased sampling efficiency ([Blower & Dowlatabadi, 1994](#); [Sweat et al., 2000](#)). 500 parameter

Table 4  
Forms of uncertainty for the model inputs for IDU 2.4

Type of data	Source of data	Sources of error
<i>Behavioural</i>	Svetlogorsk behavioural surveys among IDUs in 1997 and 1999	Relatively small sample size  Difficulties associated with sampling IDU populations In some cases different questions used in baseline and follow-up survey
<i>Transmission</i> Probability of HIV, STI transmission per sex act; probability of HIV transmission if use infected syringe; high viraemia and STI cofactors	Published literature (see Appendix A)	Variation in published estimates Limited number of estimates Estimates are from different settings
<i>Epidemiological</i> HIV prevalence of IDUs; HIV and STI prevalence of non-IDU sexual partners; duration of HIV until morbidity and STIs	Epidemiological data collected in Svetlogorsk in 1999 and published literature	Sampling error and bias in IDU HIV prevalence estimates Lack of data for HIV and STI prevalence of non-IDU sexual partners and duration of STIs
<i>Intervention and population data</i> Size of IDU population; proportion of IDUs who are male; proportion IDUs injecting for less than 1 year; coverage of intervention among IDUs	Data from Svetlogorsk project, 1999	Sampling error Conflicting estimates on the size of the IDU population Difficulties in defining and measuring intervention coverage among IDUs

sets were generated, as we found that this provides a convergent solution to the uncertainty analysis.

The model was then run for each set of input parameters, giving a frequency distribution of each of the output indicators (including cumulative HIV infections averted, and HIV prevalence among different sub-groups). An estimation of the impact of the Svetlogorsk

intervention on HIV transmission for 1997–2000 was obtained from the probability distributions of the HIV prevalence and number of HIV infections averted in the IDU and non-IDU population for each year.

#### Model validation

An indication of the reliability of the model's projections can be obtained by comparing the mean and standard deviation of the projections from the uncertainty analysis at different points in time with the intervention-specific and epidemiological data from Svetlogorsk. The data used to validate the model are: the number of condoms distributed by the intervention per year; the HIV prevalence in the registered IDU population (1999 and 2000), and estimates of the proportion of susceptible IDUs who are HIV infected each year (1997, 1998 and 1999). The HIV prevalence in the registered IDU population in 1997 is used as the initial IDU HIV prevalence for the model. The proportion of susceptible IDUs who are HIV infected each year was estimated from the proportion of registered IDUs who test HIV-positive each year (Table 3).

For the model validation the mean of the model projections in the uncertainty analysis for 1997, 1998, 1999 and 2000 was compared with the intervention and epidemiological data from Svetlogorsk.

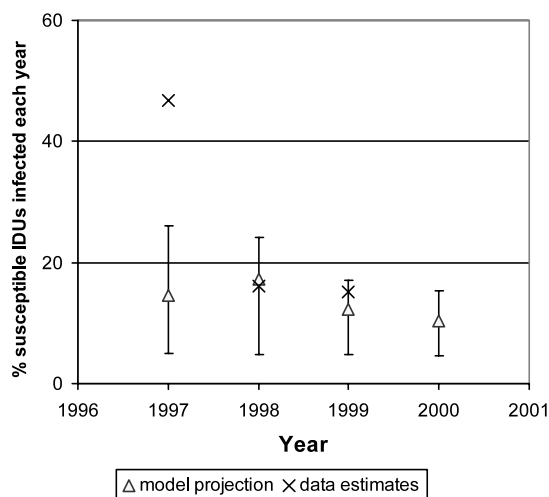


Fig. 2. Comparison of the Svetlogorsk data and model mean predictions of the proportion of susceptible IDUs that become HIV infected each year. Error bars show the 95% confidence intervals of the model predictions.

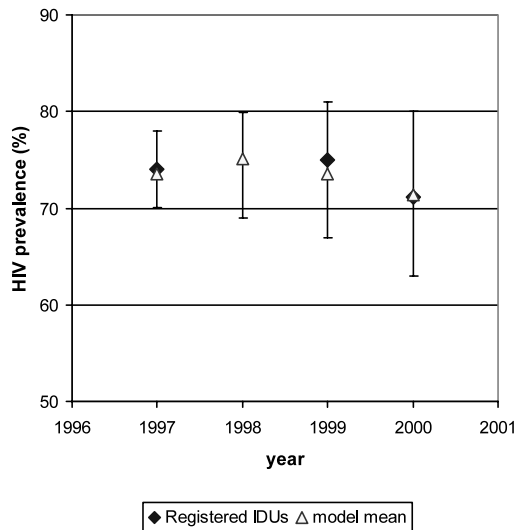


Fig. 3. Comparison of the Svetlogorsk as % confidence intervals. Error bars show 95% confidence intervals of the model predictions.

## Results

### Validation

A comparison of the outcome indicators from the Svetlogorsk data with the mean and model mean projections of estimates from the model uncertainty analysis is shown in Figs. 2 and 3.

The results in Figs. 2 and 3 show that the model projections reflect the intervention outputs in Svetlogorsk in a number of ways. Fig. 2 shows that the model's mean prediction of the percentage of susceptible IDUs who become HIV infected each year agrees closely with observation for 1998 and 1999, with 66% of the model simulations lying within the 95% confidence interval of the observed values for both years. However, the model predictions for 1997 underestimate the observed percentage of registered IDUs who tested HIV-positive that year. This results in the model predicting that during the gap in funding between 1997 and 1998 there was an 18% increase in the HIV incidence amongst susceptible IDUs, whereas the data suggests a 66% decrease (Table 3). The difference between the model predictions and observation is likely to be due to the limitations of using the 1997 data from Table 3 to estimate HIV incidence.

Fig. 3 shows that the mean predicted IDU HIV prevalence from the model simulations is close to the HIV prevalence of the registered IDU population in 1999 and 2000, with the majority of the model simulations predicting the HIV prevalence to be within the 95% confidence interval of the registered IDUs HIV prevalence for 1998 and 2000.

Many of the model simulations lie within the 95% confidence intervals of both outcome indicators for

1998, 1999 and 2000. These simulations illustrate how individual runs of the model can easily fit the Svetlogorsk data. However, they also show that it is not appropriate to assume that there is a unique input parameter set that will give an optimal fit of the model to the validation data.

The model estimates that fewer condoms are used in 1998, in accordance with the observed reduction in the number of condoms distributed that year. However, the number of condoms distributed by the intervention each year (16 000 in 1997, 11 600 in 1998 and 16 909 in 1999) is greater than the predicted mean number of additional condoms used by the IDUs due to the intervention (12 700 in 1997, 7800 in 1998, 13 000 in 1999 and 13 000 in 2000). Since the intervention provides free condoms to IDUs, and because IDUs have to pay for condoms from other sources, it is likely that most IDUs obtain the majority of their condoms from the intervention. Consequently, it is likely that IDUs replaced some of the condoms that they had previously purchased for free condoms from the intervention. It could also reflect that not all condoms acquired are used, that condoms were given away, and that in some instances, more than one condom may be used in a single sex act (Myer et al., 1999).

### Model estimation of the impact of the intervention on HIV

The model predicts that between 1997 and 2000 the intervention averted 283 HIV infections in the IDU population (95% CI, 170–380) and 131 HIV infections in the non-IDU population (95% CI, 9–335). This equates to the intervention averting a total of 414 HIV infections in Svetlogorsk from 1997 to 2000 (95% CI, 180–690). The yearly breakdown of the projected

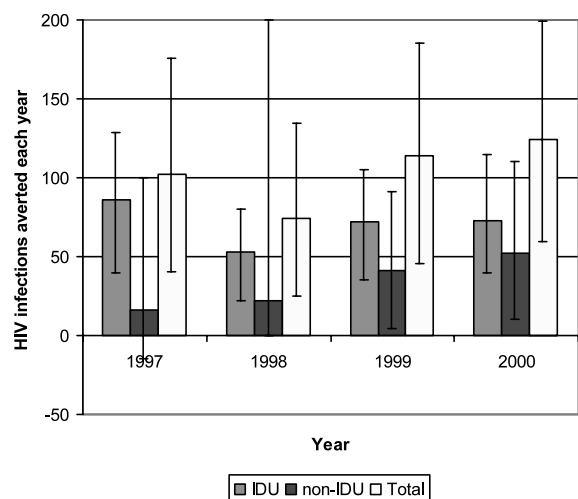


Fig. 4. Predicted HIV infections averted in Svetlogorsk from 1997 to 2000. Error bars show the 95% confidence intervals.

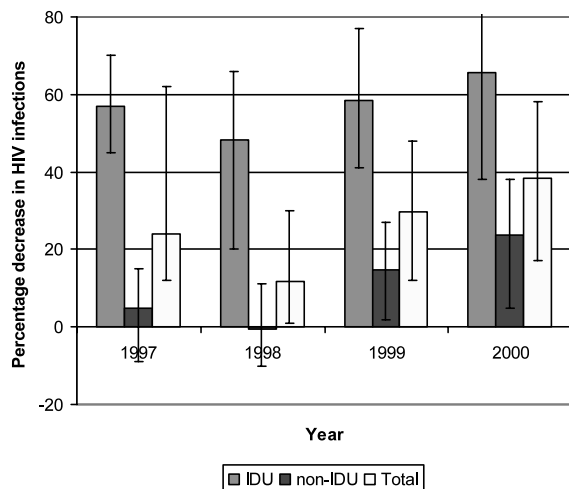


Fig. 5. Predicted percentage decrease in the number of HIV infections each year due to the needle exchange project in Svetlogorsk. Error bars show the 95% confidence intervals.

number of HIV infections averted and the percentage decrease in the number of HIV infections occurring in the IDU and non-IDU population are shown in Figs. 4 and 5.

Figs. 4 and 5 suggest that the intervention resulted in a 50–60% reduction in the yearly number of HIV infections in the IDU population (to approximately 70 per year). In 2000, this corresponds to a decrease in HIV incidence amongst susceptible IDUs from 26 per 100 person years without the intervention (95% CI, 21–35) to 10 per 100 person years with the intervention (95% CI, 5–15). This agrees with the 65% reduction in the yearly proportion of registered IDUs who test HIV-positive between 1997 and 1998 (Table 3). There was a smaller projected reduction in the yearly number of HIV infections in the non-IDU population (to approximately 30 per year). The model predicts that the 4 years of intervention activity have resulted in a 6.5% (95% CI, 1.4–13%) decrease in the IDU HIV prevalence compared to if there had been no intervention (from 77.9 to 71.4%). These predictions imply that although the HIV prevalence among IDUs has remained relatively stable between 1997 and 1999, this is likely to be the result of the intervention's activities.

The predicted mean number of HIV infections averted in the non-IDU population in all years is positive (Fig. 4). However, the 95% confidence intervals around the estimates of the number of HIV infections averted in the non-IDU population for 1997 and 1998 suggest there is a small possibility that the intervention may have had a detrimental effect on HIV transmission in non-IDUs. This is because IDUs reported a significantly greater number of non-IDU sexual partnerships after the intervention. However, this could be an artefact of the different sampling methods used to collect behavioural

data in 1997 and 1999, as IDUs who attend the intervention may be more likely to have non-IDU sexual partners. Over 4 years the estimated number of HIV infections averted in the non-IDU population is 131 (95% CI, 9–335).

There are relatively large confidence intervals around the estimates of the total HIV infections averted and the HIV infections averted among the non-IDU sexual partners of IDUs. The variability is partly due to the limited available data in Svetlogorsk on non-IDU sexual behaviour. It is also due to the HIV epidemic in the non-IDU population being in the early exponential growth phase, which results in the projected dynamics of HIV transmission being very sensitive to slight changes in the model parameters. For the analysis in Svetlogorsk, variations in the male sexual transmission and behaviour parameters contribute most to this uncertainty because the majority of the HIV transmission in the non-IDU population is between male IDUs forming sexual partnerships with female non-IDUs. Less uncertainty in the model's predictions of the number of non-IDU HIV infections averted could be obtained if greater accuracy in the size and sexual behaviour of the non-IDU population was available.

Comparing the estimated impact of the intervention with and without the gap in funding, the analysis suggests that the reduction in intervention activities between January 1998 and March 1999 resulted in a 35% reduction in the HIV infections averted in the IDU population over the time period of the gap (from 81 to 53). The model still predicts a positive mean number of HIV infections averted in the non-IDUs (Fig. 4). However, the impact is marginal and probably due to skewed data, because over the same period there is a mean percentage increase in HIV infections among non-IDUs (Fig. 5). The projections also suggest that the reduction in intervention activity also limited the intervention's impact on the IDU HIV prevalence. The model predicts that if there had been no reduction in intervention activity, then the IDU HIV prevalence would have been 72% instead of 75% in 1998 (3.3% lower, 95% CI, 2–4.9%) and 68% instead of 71% in 2000 (3.2% lower, 95% CI, 1.9–4.6%).

## Discussion

We have presented an epidemiological model, *IDU 2.4*, designed to estimate the impact on HIV transmission of interventions working with IDUs. The model was developed in collaboration with a needle exchange intervention in Svetlogorsk, Belarus. The model uses intervention, behavioural, and epidemiological data to estimate the number of HIV infections averted in the IDU and non-IDU sub-populations. The model does this by using input data to estimate the extent and forms

of behaviour change, and how this affects the needle or syringe transmission of HIV amongst IDUs, and the sexual transmission of HIV and an STI among IDUs, and between IDUs and their non-IDU sexual partners. In this article we have illustrated how the model (*IDU 2.4*) can be used to simulate HIV transmission among IDUs and their sexual partners, and to estimate the impact of HIV prevention activities focusing on IDUs and their sexual partners.

From 1997 to 2000, the model predicts that the intervention averted an average of 284 HIV infections in the IDU population in Svetlogorsk (95% CI, 170–380), prevented a 6.5% increase in the HIV prevalence among the IDUs (95% CI, 1.4–13%), and resulted in a 50–65% reduction in the yearly HIV incidence among susceptible IDUs. This corresponds to a decrease in HIV incidence among susceptible IDUs from 17.3 per 100 person years in 1997 to 10.4 per 100 person years in 2000. The results suggest that despite the uncertainty in some of the input data, even in the worst-case scenario, over 4 years the intervention has had an impact on HIV transmission amongst IDUs in Svetlogorsk. The findings highlight that NEPs can potentially reduce HIV transmission even when the HIV prevalence and incidence among IDUs is high, and despite a period of reduced intervention activity.

The model's predictions of the yearly HIV infections averted per 1000 IDUs in Svetlogorsk (65, 95% CI, 39–86) are comparable but greater than estimates obtained in other studies (10–50 HIV infections averted per 1000 IDUs per year) (Jacobs et al., 1999; Kaplan & O'Keefe, 1993; Laufer, 2001). The possibly increased impact of the intervention in Svetlogorsk may be due to a greater reduction in IDU risk behaviour in Svetlogorsk, or it may be due to the high IDU HIV incidence in Svetlogorsk resulting in a greater potential for averting HIV infections. Unfortunately, it is difficult to compare the risk behaviour of the IDUs in Svetlogorsk with the IDUs from the other studies because they did not use self-reported changes in IDU risk behaviour to estimate the HIV infections averted due to the intervention.

The percentage drop in the IDU HIV incidence in Svetlogorsk from 1997 to 2000 (approximately 42%) is comparable to the decrease in IDU HIV incidence reported from harm reduction interventions in Amsterdam (50%), Thailand (39%), New Haven (33%) and Vancouver (38%) (Brogly et al., 2000; Kaplan & O'Keefe, 1993; Schechter et al., 1999; Strathdee et al., 1997; van Ameijden & Coutinho, 1998; Vanichseni et al., 2001). However, the IDU HIV incidence in Svetlogorsk in 2000 is still very high compared to other IDU populations with active NEP interventions. The only studies that have reported similar IDU HIV incidence rates are from Vancouver and Montreal which report incidence rates of 11.8 (amongst all IDUs) and 13.8

(amongst inconsistent syringe sharers) per 100 person years, respectively (Brogly et al., 2000; Schechter et al., 1999; Strathdee et al., 1997). Other studies report much lower incidence rates of 1–6 per 100 person years (Des Jarlais et al., 2000; Kaplan & O'Keefe, 1993; van Ameijden & Coutinho, 1998; Vanichseni et al., 2001). However, the HIV prevalence of these IDU populations are all much lower than in Svetlogorsk, with none exceeding 50%, and most being lower than 30%. Therefore, the HIV incidence in Svetlogorsk may be higher purely because in this setting there is a greater chance of a susceptible IDU sharing a syringe with an infected IDU. The continued high HIV incidence rate in Svetlogorsk emphasises that more has to be done to reduce the HIV incidence further and so reverse the epidemic that is occurring amongst the IDUs.

The model predicts that the intervention would have resulted in 53% more IDU HIV infections averted in 1998 if the funding had been sustained. The detrimental impact of the gap in funding has a long-term affect on the projected HIV dynamics. Even 2 years after project funding recommenced, the IDU HIV prevalence is 3% higher (95% CI, 1.9–4.6%) and 13% fewer HIV infections were averted than if there had been no gap in funding. This emphasises the importance of ensuring continuous funding of intervention activities.

The needle exchange project did not collect any data on the population size or sexual behaviour of the non-IDU sexual partners of the IDUs, and so our estimates of the impact of the project among the non-IDU sexual partners of IDUs should be interpreted cautiously. In the first 2 years of the intervention we cannot say for certain that the intervention had a beneficial effect on the transmission of HIV to the non-IDU population. However, even after taking into account the various forms of uncertainty in the model inputs, the model predicts that over 4 years the estimated number of HIV infections averted in the non-IDU population is 131 (95% CI, 9–335). A large proportion of reached IDUs reported multiple sexual partners, with 38% of IDUs reporting one or more sexual partners per week. Over half of these sexual partners are non-IDUs and so there is a huge potential for the sexual HIV transmission to the non-IDU population. These results highlight the importance of promoting safe sex behaviours and condom use as part of the HIV prevention initiatives amongst IDUs and their sexual partners.

Published studies have looked at the impact of needle exchange programs in industrialised countries (Brogly et al., 2000; Des Jarlais et al., 2000; Donoghoe et al., 1989; Hagan et al., 1995; Hartgers et al., 1989; Holtgrave et al., 1998; Hunter et al., 1995; Kaplan & Heimer, 1994; Peak et al., 1995; Perucci et al., 1992; van Ameijden & Coutinho, 1998). However, most of these studies explored the impact of an intervention on IDU reported

risk behaviour (Donoghoe et al., 1989; Hartgers et al., 1989; Holtgrave et al., 1998; Hunter et al., 1995; Peak et al., 1995) and very few have explored how an intervention has affected the HIV incidence in the IDU population (Brogly et al., 2000; Des Jarlais et al., 2000; Kaplan & Heimer, 1994; Perucci et al., 1992; van Ameijden & Coutinho, 1998) and how many HIV infections were averted (Kaplan & O'Keefe, 1993; Jacobs et al., 1999; Laufer, 2001). Even fewer have explored the impact of a NEP on HIV transmission between IDUs and their non-IDU sexual partners (Donoghoe et al., 1989). In developing countries two published studies (in India and Nepal) have documented the effect of a needle exchange intervention on the reported risk behaviour of IDUs (Kumar et al., 1998; Peak et al., 1995). This is the first published study to estimate the number of HIV infections averted by a NEP implemented in eastern Europe, and the first to estimate the number of HIV infections averted amongst their non-IDU sexual partners. Apart from the study by Kaplan and Heimer (Kaplan & O'Keefe, 1993; Kaplan & Heimer, 1994), this is the only study that has used a dynamic epidemiological model to estimate the impact on HIV of a harm reduction intervention, and has incorporated parameter uncertainty into the impact estimates. Most other studies that have used epidemiological modelling to estimate the impact of IDU interventions on HIV transmission have used much simpler approaches to estimate intervention impact. In addition, despite the considerable uncertainty associated with the input values used in such analyses, most analyses do little or no sensitivity analysis of the impact estimates obtained (Holtgrave et al., 1998; Jacobs et al., 1999; Laufer, 2001).

The intervention in Svetlogorsk was not implemented by a research institution, and so only had limited resources for evaluation. Consequently, there are a number of limitations in the data collected by the intervention, and used in the model. Factors potentially affecting the validity of model projections and impact estimates include the attributability of the intervention effects to the NEP intervention and the reliability of the intervention, epidemiological and demographic data from Svetlogorsk. Furthermore, there are many limitations to the behavioural data used for the analysis and there is a degree of scientific uncertainty about the values of key transmission parameters. Because 'Parents for the Future of Children' was the only organisation in Svetlogorsk working with IDUs, it seems reasonable to assume that the intervention effects are mainly attributable to the intervention activities. However, it could also be that some degree of behaviour change would have resulted independently of the intervention, as a result of the high levels of HIV morbidity among IDUs. The problems encountered in the analysis with the data collected from Svetlogorsk emphasise how the evalua-

tion of harm reduction projects could be strengthened by providing training to project staff or having guidelines to aid the design of behavioural questionnaires and the sampling of and collection of behavioural data from IDUs (Burrows et al., 2000). However, as some of the data limitations will be difficult to eliminate, the findings also highlight the importance of using uncertainty analysis to identify how any model estimates of intervention impact are affected by uncertainty in the data inputs.

The needle exchange project in Svetlogorsk was initiated when the HIV prevalence in the IDU population was high. In spite of this our findings suggest that the intervention reduced HIV transmission. If the intervention had been initiated at an earlier stage of the IDU HIV epidemic it is likely that the intervention would have had a greater effect on the impact of the project (Perucci et al., 1992; Vickerman et al., 2001).

The findings have implications for other cities and regions in eastern Europe, illustrating the importance of IDU interventions both to avert further HIV transmission among IDUs, and to prevent HIV transmission between IDUs and their non-IDU sexual partners. Given that this is an important means by which HIV infection may enter the general heterosexual population, it is imperative that prevention initiatives build upon and replicate interventions such as the needle exchange programme implemented in Svetlogorsk.

### Acknowledgements

We are grateful to the "Parents for the Future of Their Children" NGO and UNAIDS Belarus who facilitated the study in Svetlogorsk. We would like to thank Anita Alban, UNAIDS Geneva, Roman Gailevich, UNAIDS Belarus, and Zoya Emelianova, our interpreter, and our colleagues Damian Walker and Lilani Kumaranayake, LSHTM, for their overall support of the research work. We would also like to thank Edward Kaplan from the Yale School of Management for giving us detailed comments on this article, and members of the UNAIDS/WHO Advisory Board who provided input during the course of the research. This article is based on research from the "Development of user-friendly tools to assist in priority-setting allocation for HIV prevention activities focusing on harm-reduction strategies project" funded by UNAIDS. Peter Vickerman is a member of the Health Economics and Financing Programme, which is funded by a programme grant from the UK Department for International Development (DFID). Charlotte Watts is a member of the Health Economics and Financing Programme and the AIDS Programme, both of which are funded by programme grants from DFID.

Appendix A. Parameter definitions, notation and value ranges for IDU 2.4

Types of model input and variables	Definition of model variables and model inputs	Range or mean (standard deviation) of model inputs for uncertainty analysis	Probability distribution of model input	Data sources for model input values
Epidemiological inputs	Initial HIV prevalence among IDUs	Male 74% (1.2%) Female 4-12 wk	Normal	HIV prevalence in IDUs tested at Narcology centre
	Average STI duration among IDUs ( $1/\mu_r$ )	2-10 wk	Triangular	Unpublished hospital data from Svetlogorsk
	Average duration of high viraemia phase ( $1/\nu$ )	6-10 wk	Uniform	Used values commonly used in other analyses (Korenromp <i>et al.</i> , 2000, Leynaert <i>et al.</i> , 1998, Seitz and Mueller 1994)
	Average duration between HIV infection and severe HIV morbidity ( $1/\delta$ )	100-148 mths	Weibull shape 2	Unpublished hospital data, Svetlogorsk
	Estimated size of population of non-IDU sexual partners	1500-6000	Uniform	Proportion of Svetlogorsk population in age range of IDUs
	Non-IDU Initial HIV prevalence	1%-5%	Uniform	Estimated from ante-natal HIV prevalence data, Svetlogorsk
	Non-IDU STI prevalence for males and females	2%-10%	Uniform	Estimated from Polyclinic data in Svetlogorsk
	Initial proportion of non-IDU sexual partners with high viraemia	5-10%	Uniform	Percentage is estimated by assuming it is a new epidemic and the high viraemia phase lasts 2 months
	Probability of HIV transmission per sex act (male to female)	0.0002-0.002	Triangular	(HIV 1992, Louria <i>et al.</i> , 2000, Royce <i>et al.</i> , 1997)
	Probability of HIV transmission per sex act (female to male)	1-3 times smaller than the male to female probability	Triangular	(HIV 1992, Louria <i>et al.</i> , 2000, Quinn <i>et al.</i> , 2000, Royce <i>et al.</i> , 1997)
Transmission probabilities	Probability of HIV transmission per needle sharing act	0.0034-0.0136	Triangular	(Hudgens <i>et al.</i> , 2002, Kaplan and Heimer 1992)
	Probability of STI transmission per sex act both sexes	0.1-0.25	Triangular	(Garnett <i>et al.</i> , 1997, Holmes <i>et al.</i> , 1970, Over and Prot 1996)
	Average STI cofactor per sex act	5-25	Triangular	Used values commonly used in other analyses (Korenromp <i>et al.</i> , 2000, Rehle <i>et al.</i> , 1998)
	Sexual transmission multiplicative factor during high viraemia phase	5-30	Triangular	Used values commonly used in other analyses (Korenromp <i>et al.</i> , 2000, Leynaert <i>et al.</i> , 1998, Seitz and Mueller 1994)
	Injecting transmission multiplicative factor during high viraemia phase	5-30	Triangular	no published estimates and so use same range as for the sexual high viraemia cofactor
	Condom efficacy per sex act	60-90%	Triangular	(Davis and Weller 1999, Pinkerton and Abramson 1997)
	Cleaning efficacy per sharing act	10-40%	Uniform	(Flynn <i>et al.</i> , 1994, Heimer 1999, Monterosso <i>et al.</i> , 2000, Shapshak <i>et al.</i> , 1994)
	Proportion of male and female IDUs that have been injecting for less than one year ( $\lambda_r$ )	0.13 (0.024)	Normal	IDU behavioural survey in Svetlogorsk, 1997 and 1999
	Rate at which IDUs leave the IDU population in the absence of HIV infection ( $\sigma_r$ )	0.053 (0.016)	Normal	Taken to equal the rate at which IDUs are recruited to the population
	Annual mortality rate (eg. sepsis or drug overdose) for male and female IDUs (per 1000 IDUs) ( $\mu_f$ )	28.3-41.4	Normal	Narcotics and infectious diseases centres, Svetlogorsk
Size of IDU population and intervention coverage	Initial size of IDU population	897-1300	Uniform	Narcotics and AIDS testing centre, Svetlogorsk
	Ratio of male to female IDU population	4.4 (1.1)	Normal	Ratio of males to females in behavioural survey 1997
	Number of IDUs attending the NEPs	500-650	Triangular	Data collected at the NEPs

Fixed needle sharing behaviour inputs	Number of 'low' and 'high' rate of needle sharing partners for IDU'S reached and not reached by the intervention	Low	1.0-3.0	Uniform	IDU behavioural survey in Svetlogorsk in 1999
Fixed sexual behaviour inputs	Definition of 'low' and 'high' frequency of needle shares per needle sharing partner for reached and not reached IDUs	High	4.0-9.0	Uniform	IDU behavioural survey in Svetlogorsk in 1999
	Degree of 'like with like' mixing between IDUs, by level of needle sharing activity (ranges from 0 to 1 - 0 for no like with like, 1 for all like with like)	Low High	0.1-0.3 2.0-5.0	Uniform Uniform	No data so used same data as for sexual 'like with like' mixing (see below)
Fixed sexual behaviour inputs	Definition of 'low' and 'high' number of sexual partners per month for males and females	Low High	0.1-0.3 2.0-5.0	Uniform Uniform	IDU behavioural surveys in Svetlogorsk, 1997 and 1999
	Definition of 'NONE', 'SOME' and 'ALL' consistency of condom use for IDUs with high numbers of sexual partners	NONE SOME ALL	0-0.2 0.2-0.6 0.6-1.0	Triangular Triangular Triangular	
	Average number of sex acts per month for IDU partnerships with a 'low' or 'high' number of sexual partnerships	Low High	5.0-15.0 1.0-5.0	Uniform Uniform	Estimated at about 1-4 sex acts per week Sex acts assumed to be less frequent than for IDUs with low number of sexual partners
	Degree of 'like with like' mixing between male and female IDU's with different levels of sexual activity (0 for no like with like, 1 with all like with like)	High	0.2-0.6	Uniform	(Aral <i>et al.</i> , 1999, Garnett <i>et al.</i> , 1996)
Sexual activity of IDU's	Population distribution of reached and not reached IDUs with respect to their level of sexual activity (with none, low or high numbers of partners)	None Low High	1- Low-High 0.5 (0.05) 0.38 (0.05)	Normal Normal Normal	No significant difference between IDU sexual behaviour from 1997 and 1999 so set the IDU sexual behaviour in 1999 to be the same as for 1997
Proportion of the IDU's sexual partners that are IDU's	Proportion of reached IDU's sexual partners that are IDU's for low and high sexual activity	Low High	0.44 (0.035) 0.63 (0.034)	Normal Normal	IDU behavioural survey in Svetlogorsk, 1999
	Proportion of not reached IDU's sexual partners that are IDU's for low and high sexual activity	Low High	0.44 (0.035) 0.63 (0.034)	Normal Normal	IDU behavioural survey in Svetlogorsk, 1997
Proportion of IDU's with different levels of needle sharing	Adjustment factor to account for possible differences in males / females reporting of the proportion of sexual partners that are IDUs (range 0 to 1 - 0 when most confident with male numbers, 1 when most confident with female numbers)	Reached Not reached	0.1-0.3 0.55 (0.035) 0.16 (0.026)	Uniform Normal Normal	No data collected on this variable in Svetlogorsk. Other studies have found that males over report their sexual behaviour (Barlow <i>et al.</i> , 1997, Gras <i>et al.</i> , 1999).
	Average consistency of cleaning syringes for reached and not reached IDU's	Reached Not reached	0.55 (0.035) 0.16 (0.026)	Normal Normal	IDU behavioural survey in Svetlogorsk, 1997 and 1999
Condom use in the IDU population	Population distribution of reached IDU's with respect to their level of needle sharing (needle sharing activity is either none, low or high)	None Low	0.65 (0.045) 1-None-High	Normal Normal	IDU behavioural survey in Svetlogorsk, 1999
	Population distribution of not reached IDU's with respect to their level of needle sharing (needle sharing activity is either none, low or high)	High None Low	0.17 (0.035) 0.08 (0.019) 1-None-High	Normal Normal Normal	IDU behavioural survey in Svetlogorsk, 1997
	Average consistency of condom use amongst 'low' sexually active IDU's	High Not reached	0.33 (0.033) 0.63 (0.034)	Normal Normal	IDU behavioural survey in Svetlogorsk, 1997 and 1999
	Distribution of condom use amongst 'high' sexually active IDU's reached by the intervention	Reached NONE SOME	0.29 (0.032) 0.37 (0.034) 0.12 (0.031)	Normal Normal Normal	IDU behavioural survey in Svetlogorsk, 1999
Condom use in the IDU population	Distribution of condom use amongst 'high' sexually active IDU's not reached by the intervention	ALL	1 - NONE--SOME	Normal	IDU behavioural survey in Svetlogorsk, 1997
	Distribution of condom use amongst 'high' sexually active IDU's not reached by the intervention	NONE SOME ALL	0.71 (0.032) 0-0.2 1 - NONE-SOME	Normal Uniform	Little data, so IDUs using condoms equally divided between the 'SOME' and 'ALL' condom use groups.
	Distribution of condom use amongst 'high' sexually active IDU's not reached by the intervention	ALL	1 - NONE-SOME	Normal	IDU behavioural survey in Svetlogorsk, 1997

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