An epidemiological model can be described by the next term

$$N_t = N_0 2^{\frac{t}{T_d}}$$

and corrected to the part of the population by dividing by total amount of the population

$$P_t = P_0 2^{\frac{t}{T_d}} \quad (1)$$

Due development of the epidemic we have restricted amount of the population and it's necessary to adapt this formula to these limitations. For this goal we will use effective reproduction number that can be calculated with next formula

$$R_t = R_0(1 - P_t) \quad (2)$$

Via simplified SEIR model [2] and some assumptions we can derivate value of the growth rate

$$G_r = \frac{R_t - 1}{D}$$

where D is infectious time (for Covid-19 was taken 10 days [1]). The dependence between doubling time and growth rate defined in the next term

$$T_d = \frac{\ln(2)}{G_r}$$

It can be extracted in the next form

$$T_d = \frac{\mathrm{D}\ln(2)}{R_t - 1}$$

We can substitute a doubling time into (1)

$$P_t = P_0 2^{\frac{t(R_t-1)}{\mathrm{D}\ln(2)}}$$

And simplify

$$P_t = P_0 e^{\frac{t(R_t-1)}{\mathrm{D}}}$$

In case if we want to calculate a value for the next day t = 1

$$P_1 = P_0 e^{\frac{R_t-1}{\mathrm{D}}}$$

The effective reproduction number can be taken from (2) with known $P_{current}$ from the previous step

$$P_{next} = P_{current} e^{\frac{R_0(1-P_{current})-1}{\mathrm{D}}}$$

The last formula has only 1 user defined parameter and allow us to calculate all other characteristics of the epidemic like saturation level, days to end, form of the curve from any selected starting epidemic point.

We also can change some values with help of the parameter μ [0…1] to see how restriction actions change epidemics development.

$$P_{next} = P_{current} e^{\frac{\mu R_0 (1 - P_{current}) - 1}{\mathrm{D}}}$$

To simplify that we can define “restriction” basic reproduction number with next term.

$$R_0' = \mu R_0$$

As soon as we have only very restricted opportunity to impact to the epidemic development by the changing of R_0' we can build a model and estimate all epidemic parameters inclusive total amount of infected population and make projection into the future with all possible actions. Initial R_0 can be calculated in the start phase of the epidemic directly from doubling time and estimated 3,5 for the Germany.

All intervention points and adapted values R_0' can be calculated with help of the regression or corrected manually.

With help of this method is possible to calculate

- Epidemic time with and without restrictions
- Deaths due the time
- Restrictions impact
- Population immunity due the time
- Lethality
- Necessity of the clinical beds

References

[1] Xi He, Eric H. Y. Lau et al. Temporal dynamics in viral shedding and transmissibility of COVID-19. https://www.nature.com/articles/s41591-020-0869-5 Nature (2020)

[2] J. M. Heffernan et al. Perspectives on the basic reproductive ratio. https://doi.org/10.1098/rsif.2005.0042 J. R. Soc. Interface 2005 2, 281–293 (2005)