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Laplace Adomian Decomposition and Navier-Stokes Modeling of Air Pollutants

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Abstract

This study presents Laplace Adomian decomposition and Navier stokes Modelling for clean air technologies analysis of some air pollutant emission sources around the world. Previous literatures showed that air pollution in the world emanated from different sources and affected the ecosystem and humans at large. Efforts made by researchers to curb the situation in the world at large yielded little result. This project developed a model and conducted simulations using pollution data obtained from global air pollution database. From the results obtained, Laplace Adomian decomposition and Navier stokes method proved to be a fine method especially with a large volume of data for predicting air pollution rates. The model can be employed in predicting pollution rate as a function of the driving parameters. The validated results showed a decrease in optimal value of 0.3% which is a novelty. Finally, when the total quantity of pollution in the atmosphere (9.65x1010m^3) was combined with 11.57 percent by volume of hydroxyl radicals, the amount of pollution in the atmosphere was reduced by 3%. They absorb these pollutants and convert them to H_2O and oxygen, which are acceptable for humans and plants to consume.

Keywords: *Laplace Adomian decomposition, Navier stokes equation, Pollution, Modeling, Clean air*

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1. Introduction

Air pollution is seen as major global threats causing serious impacts on human health and ecosystems (Franck et al., 2011; Peled, 2011). It is considered to be the major cause of premature death and disease, and the International Agency for Research on Cancer has classified it as carcinogenic (IARC, 2013). Efforts were made by different researchers in the past with sole aim of reducing the volume of pollution in the atmosphere. Several literatures in the past shows that the annual mean concentrations of NO_2 are projected to decrease by about 60% across the globe by taking cognizance of different measures that contributed to the pollution rates in the atmosphere. Annual mean $PM_{2.5}$ concentrations are also projected to fall by around 40% in the top 25% of grid squares, but by only 25% in the highest areas in some parts of the world. However, concentrations of primary $PM_{2.5}$ are projected to increase in 2035 in the world, by around 30–60% in the more polluted grid squares, as a result of the increase in biomass use. By 2050, in those two scenarios, levels are only slightly lower than 2011 values and in the highest grid square are very similar to 2011 concentrations. If this amount of primary $PM_{2.5}$ were to be removed, by avoiding the high use of biomass, total $PM_{2.5}$ concentrations could fall even further than projected, down by 50% in the highest areas compared with 25% reduction with the increased biomass use. Total PM_{10} concentrations are projected to increase in 2035 in the world, despite the reduction in secondary PM precursors, because of the increased use of biomass and the increased non-exhaust emissions from transport. PM_{10} levels decrease again by 2050, but remain only about 15% smaller than 2011 in the more polluted areas of the world. This is a small reduction and is not larger because of the increasing contribution from non-exhaust emissions. This is of concern as these emissionsare potentially toxic. The mathematical modelling of these pollutants would however give insights into the performance of these models. Therefore, it is imperative to explore other ways of curbing these pollutants before embarking on modelling. Recall, that both O_3 and NO_2 are strong oxidising agents and can play a role in oxidative stress in the human body. This can be quantified through the use of the metric O_x or oxidant ($O_x = O_3 + NO_2$), which has been shown to be associated with adverse health outcomes. Annual average levels are projected to remain virtually constant to 2050. The significance of this for health is that the balance of O_x will shift to O_3 as NO_2 reduces; the former is the more powerful O_x so that the oxidising power of the urban atmosphere in the world will increase with potentially increased adverse health effects, assuming that the global background of O_3 remains broadly constant Moreover, NO2 is partly responsible for the acidification of soils and waters. Ozone is a secondary air pollutant that affects agricultural crops, forests by reducing plant growth (Wang *et al.*, 2007). Both ozone and particulate matter (PM) contributes to global warming (Hansen *et al.,* 2001). Human's lives are also affected by pollution (OECD, 2016; Trippetta *et al.,* 2016). These pollutants made international communities to come up with policies that will reduce them. Air pollution, nowadays is seen as the biggest threat to humans (Lorenzoni and Pidgeon, 2006; Krzyzanowski and Cohen, 2008), as well as the United Nations Sustainable Development Goals (Griggs *et al.*, 2013; Kumar *et al.*, 2018; Bellies *et al.*, 2013; Yatkin and Bayram 2007) Moreover, several studies have been performed on the relationship of pollution and its causes in many parts of the world (Salcedo, 1999; Alimissis, 2018; Lin *et al.,* 2018; Elangasinghe *et al.,* 2014; Huang *et al*., 2019), and these are aimed at reduction in pollution rates and its spread in the atmosphere. Air pollution is concerned with the introduction of chemicals, particulate matter, or biological materials into the atmosphere. These in turn causes discomfort to humans and other living organisms and the ecosystem (Biswanat *et al.*, 2009). Because the introduction of chemicals and other polluting substances is not limited, models which relate the pollution rate and any pollutants must be continuously renewed to reflect any potent indicators which can seriously increase pollution. Accordingly, this study examined existing pollution correlation models and incorporated novel pollution causing indicators in a regression analysis using a pool of large data across several continents. Due to the health implication of severely polluted environments, it is imperative to relate major drivers of pollution using a large volume of data. Such analysis will suggest to what extent these pollution indicators can be reduced to remedy the ecosystem and humans on its effect. In literature, very limited indicators are often related to the quantity of pollution rate and can severely thwart efforts aimed at remediating pollution. In the light of the foregoing, the present study is justified by virtue of the empirical introduction of novel pollution dependent indicators in a pool of large data to make forecast based regression model of pollution rate. It will help in striking a balance on the extent success can be recorded in reducing pollution rate in the future.

2. Materials and methods

2.1 Laplace Adomian Decomposition Method and Navier-Stokes modelling

The mathematical formulation for laplace adomian decomposition and Navier Stokes is represented below:

$$D_t{}^{\beta}(f_{co}) + f_{co}\frac{\delta f_{co}}{\delta x_1} + f_{co}\frac{\delta f_{co}}{\delta x_2} + f_{co}\frac{\delta f_{co}}{\delta x_3} = \rho[\frac{\delta^2 f_{co}}{\delta_{x_1}{}^2} + \frac{\delta^2 f_{co}}{\delta_{x_2}{}^2} + \frac{\delta^2 f_{co}}{\delta_{x_3}{}^2}] \quad (1)$$

$$D_t{}^{\beta}(f_{NO}) + f_{NO}\frac{\delta f_{NO}}{\delta x_1} + f_{NO}\frac{\delta f_{NO}}{\delta x_2} + f_{NO}\frac{\delta f_{NO}}{\delta x_3} = \rho[\frac{\delta^2 f_{NO}}{\delta_{x_1}{}^2} + \frac{\delta^2 f_{NO}}{\delta_{x_2}{}^2} + \frac{\delta^2 f_{NO}}{\delta_{x_3}{}^2}] \quad (2)$$

$$D_t{}^{\beta}(f_{NO_2}) + f_{NO_2}\frac{\delta f_{NO_2}}{\delta x_1} + f_{NO_2}\frac{\delta f_{NO_2}}{\delta x_2} + f_{NO_2}\frac{\delta f_{NO_2}}{\delta x_3} = \rho[\frac{\delta^2 f_{NO_2}}{\delta_{x_1}{}^2} + \frac{\delta^2 f_{NO_2}}{\delta_{x_2}{}^2} + \frac{\delta^2 f_{NO_2}}{\delta_{x_3}{}^2}] \quad (3)$$

$$D_t{}^{\beta}(f_{SO_2}) + f_{SO_2}\frac{\delta f_{SO_2}}{\delta x_1} + f_{SO_2}\frac{\delta f_{SO_2}}{\delta x_2} + f_{SO_2}\frac{\delta f_{SO_2}}{\delta x_3} = \rho[\frac{\delta^2 f_{SO_2}}{\delta_{x_1}{}^2} + \frac{\delta^2 f_{SO_2}}{\delta_{x_2}{}^2} + \frac{\delta^2 f_{SO_2}}{\delta_{x_3}{}^2}] \quad (4)$$

$$D_t{}^{\beta}(f_{O_3}) + f_{O_3}\frac{\delta f_{O_3}}{\delta x_1} + f_{O_3}\frac{\delta f_{O_3}}{\delta x_2} + f_{O_3}\frac{\delta f_{O_3}}{\delta x_3} = \rho[\frac{\delta^2 f_{O_3}}{\delta_{x_1}{}^2} + \frac{\delta^2 f_{O_3}}{\delta_{x_2}{}^2} + \frac{\delta^2 f_{O_3}}{\delta_{x_3}{}^2}] \quad (5)$$

$$D_t^{\beta}(f_{pm}) + f_{pm}\frac{\delta f_{pm}}{\delta x_1} + f_{pm}\frac{\delta f_{pm}}{\delta x_2} + f_{pm}\frac{\delta f_{pm}}{\delta x_3} = \rho[\frac{\delta^2 f_{pm}}{\delta_{x_1}{}^2} + \frac{\delta^2 f_{pm}}{\delta_{x_2}{}^2} + \frac{\delta^2 f_{pm}}{\delta_{x_3}{}^2}] \tag{6}$$

$$D_t^{\beta}(f_{pb}) + f_{pb}\frac{\delta f_{pb}}{\delta x_1} + f_{pb}\frac{\delta f_{pb}}{\delta x_2} + f_{pb}\frac{\delta f_{pb}}{\delta x_3} = \rho\left[\frac{\delta^2 f_{pb}}{\delta_{x_1}{}^2} + \frac{\delta^2 f_{pb}}{\delta_{x_2}{}^2} + \frac{\delta^2 f_{pb}}{\delta_{x_3}{}^2}\right] - \frac{1}{\rho}\frac{\delta\rho}{\delta x_3} \tag{7}$$

With initial conditions:

$$f_{co}(x_1, x_2, x_3, 0) = f(x_1, x_2, x_3) \tag{8}$$

$$f_{NO}(x_1, x_2, x_3, 0) = h(x_1, x_2, x_3) \tag{9}$$

$$f_{NO_2}(x_1, x_2, x_3, 0) = g(x_1, x_2, x_3) \tag{10}$$

$$f_{SO_2}(x_1, x_2, x_3, 0) = i(x_1, x_2, x_3) \tag{11}$$

$$f_{O_3}(x_1, x_2, x_3, 0) = j(x_1, x_2, x_3) \tag{12}$$

$$f_{pm}(x_1, x_2, x_3, 0) = k(x_1, x_2, x_3) \tag{13}$$

$$f_{pb}(x_1, x_2, x_3, 0) = l(x_1, x_2, x_3) \tag{14}$$

The Laplace transformation is represented below;

$$\mathcal{L}[D_t^{\beta}(f_{co})] + \mathcal{L}[f_{co}\frac{\delta f_{co}}{\delta x_1} + f_{co}\frac{\delta f_{co}}{\delta x_2} + f_{co}\frac{\delta f_{co}}{\delta x_3}] = \mathcal{L}\rho\left[\frac{\delta^2 f_{co}}{\delta_{x_1}{}^2} + \frac{\delta^2 f_{co}}{\delta_{x_2}{}^2} + \frac{\delta^2 f_{co}}{\delta_{x_3}{}^2}\right] - \mathcal{L}[\frac{1}{\rho}\frac{\delta\rho}{\delta x_{c0}}] \tag{15}$$

$$\mathcal{L}[D_t^{\beta}(f_{NO})] + \mathcal{L}[f_{NO}\frac{\delta f_{NO}}{\delta x_1} + f_{NO}\frac{\delta f_{NO}}{\delta x_2} + f_{NO}\frac{\delta f_{NO}}{\delta x_3}] = \mathcal{L}\rho[\frac{\delta^2 f_{NO}}{\delta_{x_1}{}^2} + \frac{\delta^2 f_{NO}}{\delta_{x_2}{}^2} + \frac{\delta^2 f_{NO}}{\delta_{x_3}{}^2}] - \mathcal{L}[\frac{1}{\rho}\frac{\delta\rho}{\delta x_{NO}}] \tag{16}$$

$$\mathcal{L}[D_t^{\beta}(f_{NO_2})] + \mathcal{L}[f_{NO_2}\frac{\delta f_{NO_2}}{\delta x_1} + f_{NO_2}\frac{\delta f_{NO_2}}{\delta x_2} + f_{NO_2}\frac{\delta f_{NO_2}}{\delta x_3}] = \mathcal{L}\rho[\frac{\delta^2 f_{NO_2}}{\delta_{x_1}{}^2} + \frac{\delta^2 f_{NO_2}}{\delta_{x_2}{}^2} + \frac{\delta^2 f_{NO_2}}{\delta_{x_3}{}^2}] - \mathcal{L}[\frac{1}{\rho}\frac{\delta\rho}{\delta x_{NO_2}}] \tag{17}$$

$$\mathcal{L}[D_t^{\beta}(f_{SO_2})] + \mathcal{L}[f_{SO_2}\frac{\delta f_{SO_2}}{\delta x_1} + f_{SO_2}\frac{\delta f_{SO_2}}{\delta x_2} + f_{SO_2}\frac{\delta f_{SO_2}}{\delta x_3}] = \mathcal{L}\rho[\frac{\delta^2 f_{SO_2}}{\delta_{x_1}{}^2} + \frac{\delta^2 f_{SO_2}}{\delta_{x_2}{}^2} + \frac{\delta^2 f_{SO_2}}{\delta_{x_3}{}^2}] - \mathcal{L}[\frac{1}{\rho}\frac{\delta\rho}{\delta x_{SO_2}}] \tag{18}$$

$$\mathcal{L}[D_t^{\beta}(f_{O_3})] + \mathcal{L}[f_{O_3}\frac{\delta f_{O_3}}{\delta x_1} + f_{O_3}\frac{\delta f_{O_3}}{\delta x_2} + f_{O_3}\frac{\delta f_{O_3}}{\delta x_3}] = \mathcal{L}\rho[\frac{\delta^2 f_{O_3}}{\delta_{x_1}{}^2} + \frac{\delta^2 f_{O_3}}{\delta_{x_2}{}^2} + \frac{\delta^2 f_{O_3}}{\delta_{x_3}{}^2}] - \mathcal{L}[\frac{1}{\rho}\frac{\delta\rho}{\delta x_{O_3}}] \tag{19}$$

$$\mathcal{L}[D_t^{\beta}(f_{pm})] + \mathcal{L}[f_{pm}\frac{\delta f_{pm}}{\delta x_1} + f_{pm}\frac{\delta f_{pm}}{\delta x_2} + f_{pm}\frac{\delta f_{pm}}{\delta x_3}] = \mathcal{L}\rho[\frac{\delta^2 f_{pm}}{\delta_{x_1}{}^2} + \frac{\delta^2 f_{pm}}{\delta_{x_2}{}^2} + \frac{\delta^2 f_{pm}}{\delta_{x_3}{}^2}] - \mathcal{L}[\frac{1}{\rho}\frac{\delta\rho}{\delta x_{pm}}] \tag{20}$$

$$\mathcal{L}[D_t^{\beta}(f_{pb})] + \mathcal{L}[f_{pb}\frac{\delta f_{pb}}{\delta x_1} + f_{pb}\frac{\delta f_{pb}}{\delta x_2} + f_{pb}\frac{\delta f_{pb}}{\delta x_3}] = \mathcal{L}\rho\left[\frac{\delta^2 f_{pb}}{\delta_{x_1}{}^2} + \frac{\delta^2 f_{pb}}{\delta_{x_2}{}^2} + \frac{\delta^2 f_{pb}}{\delta_{x_3}{}^2}\right] - \mathcal{L}[\frac{1}{\rho}\frac{\delta\rho}{\delta x_{pb}}] \tag{21}$$

Applying differentiation property of Laplace transform

$$\mathcal{L}(f_{co}) = \frac{f(x_1,x_2,x_3)}{s} - \frac{1}{s^{\beta}}\mathcal{L}\left[f_{co}\frac{\delta f_{co}}{\delta x_1} + f_{co}\frac{\delta f_{co}}{\delta x_2} + f_{co}\frac{\delta f_{co}}{\delta x_3}\right] + \frac{\rho}{s^{\beta}}\mathcal{L}\left[\frac{\delta^2 f_{co}}{\delta x_1{}^2} + \frac{\delta^2 f_{co}}{\delta x_2{}^2} + \frac{\delta^2 f_{co}}{\delta x_3{}^2}\right] - \frac{1}{s^{\beta}}\mathcal{L}\left[\frac{1}{\rho}\frac{\delta\rho}{\delta x_{co}}\right], \tag{22}$$

$$\mathcal{L}(f_{NO}) = \frac{f(x_1,x_2,x_3)}{s} - \frac{1}{s^{\beta}}\mathcal{L}\left[f_{NO}\frac{\delta f_{NO}}{\delta x_1} + f_{NO}\frac{\delta f_{NO}}{\delta x_2} + f_{NO}\frac{\delta f_{NO}}{\delta x_3}\right] + \frac{\rho}{s^{\beta}}\mathcal{L}\left[\frac{\delta^2 f_{NO}}{\delta x_1{}^2} + \frac{\delta^2 f_{NO}}{\delta x_2{}^2} + \frac{\delta^2 f_{NO}}{\delta x_3{}^2}\right] - \frac{1}{s^{\beta}}\mathcal{L}\left[\frac{1}{\rho}\frac{\delta\rho}{\delta x_{NO}}\right], \tag{23}$$

$$\mathcal{L}(f_{NO_2}) = \frac{f(x_1,x_2,x_3)}{s} - \frac{1}{s^\beta}\mathcal{L}\left[f_{NO_2}\frac{\delta f_{NO_2}}{\delta x_1} + f_{NO_2}\frac{\delta f_{NO_2}}{\delta x_2} + f_{NO_2}\frac{\delta f_{NO_2}}{\delta x_3}\right] + \frac{\rho}{s^\beta}\mathcal{L}\left[\frac{\delta^2 f_{NO_2}}{\delta {x_1}^2} + \frac{\delta^2 f_{NO_2}}{\delta {x_2}^2} + \frac{\delta^2 f_{NO_2}}{\delta {x_3}^2}\right] - \frac{1}{s^\beta}\mathcal{L}\left[\frac{1}{\rho}\frac{\delta\rho}{\delta x_{NO_2}}\right], \quad (24)$$

$$\mathcal{L}(f_{O_3}) = \frac{f(x_1,x_2,x_3)}{s} - \frac{1}{s^\beta}\mathcal{L}\left[f_{O_3}\frac{\delta f_{O_3}}{\delta x_1} + f_{O_3}\frac{\delta f_{O_3}}{\delta x_2} + f_{O_3}\frac{\delta f_{O_3}}{\delta x_3}\right] + \frac{\rho}{s^\beta}\mathcal{L}\left[\frac{\delta^2 f_{O_3}}{\delta {x_1}^2} + \frac{\delta^2 f_{O_3}}{\delta {x_2}^2} + \frac{\delta^2 f_{O_3}}{\delta {x_3}^2}\right] - \frac{1}{s^\beta}\mathcal{L}\left[\frac{1}{\rho}\frac{\delta\rho}{\delta x_{O_3}}\right], (25)$$

$$\mathcal{L}(f_{SO_2}) = \frac{f(x_1,x_2,x_3)}{s} - \frac{1}{s^\beta}\mathcal{L}\left[f_{SO_2}\frac{\delta f_{SO_2}}{\delta x_1} + f_{SO_2}\frac{\delta f_{SO_2}}{\delta x_2} + f_{SO_2}\frac{\delta f_{SO_2}}{\delta x_3}\right] + \frac{\rho}{s^\beta}\mathcal{L}\left[\frac{\delta^2 f_{SO_2}}{\delta {x_1}^2} + \frac{\delta^2 f_{SO_2}}{\delta {x_2}^2} + \frac{\delta^2 f_{SO_2}}{\delta {x_3}^2}\right] - \frac{1}{s^\beta}\mathcal{L}\left[\frac{1}{\rho}\frac{\delta\rho}{\delta x_{SO_2}}\right], \quad (26)$$

$$\mathcal{L}(f_{pm}) = \frac{f(x_1,x_2,x_3)}{s} - \frac{1}{s^\beta}\mathcal{L}\left[f_{pm}\frac{\delta f_{pm}}{\delta x_1} + f_{pm}\frac{\delta f_{pm}}{\delta x_2} + f_{pm}\frac{\delta f_{pm}}{\delta x_3}\right] + \frac{\rho}{s^\beta}\mathcal{L}\left[\frac{\delta^2 f_{pm}}{\delta {x_1}^2} + \frac{\delta^2 f_{pm}}{\delta {x_2}^2} + \frac{\delta^2 f_{pm}}{\delta {x_3}^2}\right] - \frac{1}{s^\beta}\mathcal{L}\left[\frac{1}{\rho}\frac{\delta\rho}{\delta x_{pm}}\right], \quad (27)$$

$$\mathcal{L}(f_{pb}) = \frac{f(x_1,x_2,x_3)}{s} - \frac{1}{s^\beta}\mathcal{L}\left[f_{pb}\frac{\delta f_{pb}}{\delta x_1} + f_{pb}\frac{\delta f_{pb}}{\delta x_2} + f_{pb}\frac{\delta f_{pb}}{\delta x_3}\right] + \frac{\rho}{s^\beta}\mathcal{L}\left[\frac{\delta^2 f_{pb}}{\delta {x_1}^2} + \frac{\delta^2 f_{pb}}{\delta {x_2}^2} + \frac{\delta^2 f_{pb}}{\delta {x_3}^2}\right] - \frac{1}{s^\beta}\mathcal{L}\left[\frac{1}{\rho}\frac{\delta\rho}{\delta x_{pb}}\right], \quad (28)$$

The Adomian solutions can be written as:

$$f_{co}(x_1, x_2, x_3, t) = \sum_{j=0}^{\infty} t_j \quad (29)$$

$$f_{No}(x_1, x_2, x_3, t) = \sum_{j=0}^{\infty} u_j \quad (30)$$

$$f_{NO_2}(x_1, x_2, x_3, t) = \sum_{j=0}^{\infty} v_j \quad (31)$$

$$f_{SO_2}(x_1, x_2, x_3, t) = \sum_{j=0}^{\infty} w_j$$

$$f_{O_3}(x_1, x_2, x_3, t) = \sum_{j=0}^{\infty} x_j \quad (32)$$

$$f_{pm}(x_1, x_2, x_3, t) = \sum_{j=0}^{\infty} y_j \quad (33)$$

$$f_{pb}(x_1, x_2, x_3, t) = \sum_{j=0}^{\infty} z_j \quad (34)$$

The nonlinear terms are defined by infinite series of Adomian polynomials,

$$N_{co}(f_{co}) = \sum_{j=0}^{\infty} A_j \quad (35)$$

$$N_{No}(f_{NO}) = \sum_{j=0}^{\infty} B_j \quad (36)$$

$$N_{NO_2}(f_{NO_2}) = \sum_{j=0}^{\infty} C_j \quad (37)$$

$$N_{SO_2}(f_{SO_2}) = \sum_{j=0}^{\infty} D_j \quad (38)$$

$$N_{O_3}(f_{O_3}) = \sum_{j=0}^{\infty} E_j \quad (39)$$

$$N_{pm}(f_{pm}) = \sum_{j=0}^{\infty} F_j$$

$$N_{pb}(f_{pb}) = \sum_{j=0}^{\infty} G_j \quad (40)$$

$$A_j = \frac{1}{j!}\left[\frac{d^j}{d\lambda^j}\left[N_{co}\sum_{i=0}^{\infty}(\lambda^j u_j)\right]\right]_{\lambda=0} \quad (41)$$

$$B_j = \frac{1}{j!}\left[\frac{d^j}{d\lambda^j}\left[N_{NO}\sum_{i=0}^{\infty}(\lambda^j u_j)\right]\right]_{\lambda=0} \quad (42)$$

$$C_j = \frac{1}{j!}\left[\frac{d^j}{d\lambda^j}\left[N_{NO_2}\sum_{i=0}^{\infty}(\lambda^j u_j)\right]\right]_{\lambda=0} \quad (43)$$

$$D_j = \frac{1}{j!}\left[\frac{d^j}{d\lambda^j}\left[N_{SO_2}\sum_{i=0}^{\infty}(\lambda^j u_j)\right]\right]_{\lambda=0} \quad (44)$$

$$E_j = \frac{1}{j!}\left[\frac{d^j}{d\lambda^j}\left[N_{O_3}\sum_{i=0}^{\infty}(\lambda^j u_j)\right]\right]_{\lambda=0} \quad (45)$$

$$F_j = \frac{1}{j!}\left[\frac{d^j}{d\lambda^j}\left[N_{pm}\sum_{i=0}^{\infty}(\lambda^j u_j)\right]\right]_{\lambda=0} \quad (46)$$

$$G_j = \frac{1}{j!}\left[\frac{d^j}{d\lambda^j}\left[N_{pb}\sum_{i=0}^{\infty}(\lambda^j u_j)\right]\right]_{\lambda=0} \quad (47)$$

Using LADM solutions in Equations (22) to (28)

$$\mathcal{L}(\sum_{j=0}^{\infty} t_{j+1}) = \frac{(fx_1,x_2,x_3)}{s} - \frac{1}{s^\beta}\mathcal{L}\left(\frac{1}{\rho}\frac{\delta\rho}{\delta x_1}\right) - \frac{1}{s^\beta}\mathcal{L}[(\sum_{j=0}^{\infty} f_{co})\frac{\delta(\sum_{j=0}^{\infty} f_{co})}{\delta x_1} + (\sum_{j=0}^{\infty} f_{co})\frac{\delta(\sum_{j=0}^{\infty} f_{co}}{\delta x_2} + (\sum_{j=0}^{\infty} f_{co})\frac{\delta(\sum_{j-0}^{\infty} f_{co})}{\delta x_3} + \frac{\rho}{s^\beta}\mathcal{L}[\frac{(\delta^2(\sum_{j=0}^{\infty} f_{co})}{\delta {x_1}^2} + \frac{(\delta^2(\sum_{j=0}^{\infty} f_{co})}{\delta {x_2}^2} + \frac{(\delta^2(\sum_{j=0}^{\infty} f_{co})}{\delta {x_3}^2} \quad (48)$$

$$\mathcal{L}(\sum_{j=0}^{\infty} t_{j+1}) = \frac{(fx_1,x_2,x_3)}{s} - \frac{1}{s^\beta}\mathcal{L}\left(\frac{1}{\rho}\frac{\delta\rho}{\delta x_1}\right) - \frac{1}{s^\beta}\mathcal{L}[(\sum_{j=0}^{\infty} f_{NO})\frac{\delta(\sum_{j=0}^{\infty} f_{NO})}{\delta x_1} + (\sum_{j=0}^{\infty} f_{NO})\frac{\delta(\sum_{j=0}^{\infty} f_{NO}}{\delta x_2} + (\sum_{j=0}^{\infty} f_{NO})\frac{\delta(\sum_{j-0}^{\infty} f_{NO})}{\delta x_3} + \frac{\rho}{s^\beta}\mathcal{L}[\frac{(\delta^2(\sum_{j=0}^{\infty} f_{NO})}{\delta {x_1}^2} + \frac{(\delta^2(\sum_{j=0}^{\infty} f_{NO})}{\delta {x_2}^2} + \frac{(\delta^2(\sum_{j=0}^{\infty} f_{NO})}{\delta {x_3}^2} \quad (49)$$

$$\mathcal{L}(\sum_{j=0}^{\infty} t_{j+1}) = \frac{(fx_1,x_2,x_3)}{s} - \frac{1}{s^\beta}\mathcal{L}\left(\frac{1}{\rho}\frac{\delta\rho}{\delta x_1}\right) - \frac{1}{s^\beta}\mathcal{L}[(\sum_{j=0}^{\infty} f_{NO_2})\frac{\delta(\sum_{j=0}^{\infty} f_{NO_2})}{\delta x_1} + (\sum_{j=0}^{\infty} f_{NO_2})\frac{\delta(\sum_{j=0}^{\infty} f_{NO_2}}{\delta x_2} + (\sum_{j=0}^{\infty} f_{NO_2})\frac{\delta(\sum_{j-0}^{\infty} f_{NO_2})}{\delta x_3} + \frac{\rho}{s^\beta}\mathcal{L}[\frac{(\delta^2(\sum_{j=0}^{\infty} f_{NO_2})}{\delta {x_1}^2} + \frac{(\delta^2(\sum_{j=0}^{\infty} f_{NO_2})}{\delta {x_2}^2} + \frac{(\delta^2(\sum_{j=0}^{\infty} f_{NO_2})}{\delta {x_3}^2} \quad (50)$$

$$\mathcal{L}(\sum_{j=0}^{\infty} t_{j+1}) = \frac{(fx_1,x_2,x_3)}{s} - \frac{1}{s^\beta}\mathcal{L}\left(\frac{1}{\rho}\frac{\delta\rho}{\delta x_1}\right) - \frac{1}{s^\beta}\mathcal{L}[(\sum_{j=0}^{\infty} f_{SO_2})\frac{\delta(\sum_{j=0}^{\infty} f_{SO_2})}{\delta x_1} + (\sum_{j=0}^{\infty} f_{SO_2})\frac{\delta(\sum_{j=0}^{\infty} f_{SO_2}}{\delta x_2} + (\sum_{j=0}^{\infty} f_{SO_2})\frac{\delta(\sum_{j-0}^{\infty} f_{SO_2})}{\delta x_3} + \frac{\rho}{s^\beta}\mathcal{L}[\frac{(\delta^2(\sum_{j=0}^{\infty} f_{SO_2})}{\delta {x_1}^2} + \frac{(\delta^2(\sum_{j=0}^{\infty} f_{SO_2})}{\delta {x_2}^2} + \frac{(\delta^2(\sum_{j=0}^{\infty} f_{SO_2})}{\delta {x_3}^2} \quad (51)$$

$$\mathcal{L}(\sum_{j=0}^{\infty} t_{j+1}) = \frac{(fx_1,x_2,x_3)}{s} - \frac{1}{s^\beta}\mathcal{L}\left(\frac{1}{\rho}\frac{\delta\rho}{\delta x_1}\right) - \frac{1}{s^\beta}\mathcal{L}[(\sum_{j=0}^{\infty} f_{O_3})\frac{\delta(\sum_{j=0}^{\infty} f_{O_3})}{\delta x_1} + (\sum_{j=0}^{\infty})\frac{\delta(\sum_{j=0}^{\infty} f_{O_3}}{\delta x_2} + (\sum_{j=0}^{\infty} f_{O_3})\frac{\delta(\sum_{j-0}^{\infty} f_{O_3})}{\delta x_3} + \frac{\rho}{s^\beta}\mathcal{L}[\frac{(\delta^2(\sum_{j=0}^{\infty} f_{O_3})}{\delta {x_1}^2} + \frac{(\delta^2(\sum_{j=0}^{\infty} f_{O_3})}{\delta {x_2}^2} + \frac{(\delta^2(\sum_{j=0}^{\infty} f_{O_3})}{\delta {x_3}^2} \quad (52)$$

$$\mathcal{L}(\sum_{j=0}^{\infty} t_{j+1}) = \frac{(fx_1,x_2,x_3)}{s} - \frac{1}{s^\beta}\mathcal{L}\left(\frac{1}{\rho}\frac{\delta\rho}{\delta x_1}\right) - \frac{1}{s^\beta}\mathcal{L}[(\sum_{j=0}^{\infty} f_{pm})\frac{\delta(\sum_{j=0}^{\infty} f_{pm})}{\delta x_1} + (\sum_{j=0}^{\infty} f_{pm})\frac{\delta(\sum_{j=0}^{\infty} f_{pm}}{\delta x_2} + (\sum_{j=0}^{\infty} f_{pm})\frac{\delta(\sum_{j-0}^{\infty} f_{pm})}{\delta x_3} + \frac{\rho}{s^\beta}\mathcal{L}[\frac{(\delta^2(\sum_{j=0}^{\infty} f_{pm})}{\delta {x_1}^2} + \frac{(\delta^2(\sum_{j=0}^{\infty} f_{pm})}{\delta {x_2}^2} + \frac{(\delta^2(\sum_{j=0}^{\infty} f_{pm})}{\delta {x_3}^2} \quad (53)$$

$$\mathcal{L}(\sum_{j=0}^{\infty} t_{j+1}) = \frac{(fx_1,x_2,x_3)}{s} - \frac{1}{s^\beta}\mathcal{L}\left(\frac{1}{\rho}\frac{\delta\rho}{\delta x_1}\right) - \frac{1}{s^\beta}\mathcal{L}[(\sum_{j=0}^{\infty} f_{pb})\frac{\delta(\sum_{j=0}^{\infty} f_{pb})}{\delta x_1} + (\sum_{j=0}^{\infty} f_{pb})\frac{\delta(\sum_{j=0}^{\infty} f_{pb}}{\delta x_2} + (\sum_{j=0}^{\infty} f_{pb})\frac{\delta(\sum_{j-0}^{\infty} f_{pb})}{\delta x_3} + \frac{\rho}{s^\beta}\mathcal{L}[\frac{(\delta^2(\sum_{j=0}^{\infty} f_{pb})}{\delta {x_1}^2} + \frac{(\delta^2(\sum_{j=0}^{\infty} f_{pb})}{\delta {x_2}^2} + \frac{(\delta^2(\sum_{j=0}^{\infty} f_{pb})}{\delta {x_3}^2} \quad (54)$$

Applying Laplace transform in order to confirm linearity of pollutants:

$$\mathcal{L}(t_0) = \frac{f(x_1,x_2,x_3)}{s} + \frac{1}{s^\beta}\mathcal{L}\left(\frac{1}{\rho}\frac{\delta\rho}{\delta x_{co}}\right), \quad (55)$$

$$\mathcal{L}(u_0) = \frac{f(x_1,x_2,x_3)}{s} + \frac{1}{s^\beta}\mathcal{L}\left(\frac{1}{\rho}\frac{\delta\rho}{\delta x_{NO}}\right),$$

$$\mathcal{L}(v_0) = \frac{f(x_1,x_2,x_3)}{s} + \frac{1}{s^\beta}\mathcal{L}\left(\frac{1}{\rho}\frac{\delta\rho}{\delta x_{NO_2}}\right),$$

$$\mathcal{L}(w_0) = \frac{f(x_1,x_2,x_3)}{s} + \frac{1}{s^\beta}\mathcal{L}\left(\frac{1}{\rho}\frac{\delta\rho}{\delta x_{SO_2}}\right),$$

$$\mathcal{L}(x_0) = \frac{f(x_1,x_2,x_3)}{s} + \frac{1}{s^\beta}\mathcal{L}\left(\frac{1}{\rho}\frac{\delta\rho}{\delta x_{O_3}}\right),$$

$$\mathcal{L}(y_0) = \frac{f(x_1,x_2,x_3)}{s} + \frac{1}{s^\beta}\mathcal{L}\left(\frac{1}{\rho}\frac{\delta\rho}{\delta x_{pm}}\right),$$

$$\mathcal{L}(z_0) = \frac{f(x_1,x_2,x_3)}{s} + \frac{1}{s^\beta}\mathcal{L}\left(\frac{1}{\rho}\frac{\delta\rho}{\delta x_{pb}}\right),$$

$$\mathcal{L}(\sum_{j=0}^{\infty} t_{j+1}) = -\frac{1}{s^\beta}\mathcal{L}[(\sum_{j=0}^{\infty} f_{coj})\frac{\delta(\sum_{j=0}^{\infty} f_{coj}}{\delta x_1} + \sum_{j=0}^{\infty} f_{coj})\frac{\delta(\sum_{j=0}^{\infty} f_{coj}}{\delta x_2} + \sum_{j=0}^{\infty} f_{coj})\frac{\delta(\sum_{j=0}^{\infty} f_{coj}}{\delta x_3} + \frac{\rho}{s^\beta}\mathcal{L}[\frac{\delta^2\ (\sum_{j=0}^{\infty} f_{coj}}{\delta {x^2}_1} + \frac{\delta^2\ (\sum_{j=0}^{\infty} f_{coj}}{\delta {x^2}_2} + \frac{\delta^2\ (\sum_{j=0}^{\infty} f_{coj}}{\delta {x^2}_3}]$$

$$\mathcal{L}(\sum_{j=0}^{\infty} u_{j+1}) = -\frac{1}{s^\beta}\mathcal{L}[(\sum_{j=0}^{\infty} f_{NOj})\frac{\delta(\sum_{j=0}^{\infty} f_{NOj}}{\delta x_1} + \sum_{j=0}^{\infty} f_{NOj})\frac{\delta(\sum_{j=0}^{\infty} f_{NOj}}{\delta x_2} + \sum_{j=0}^{\infty} f_{NOj})\frac{\delta(\sum_{j=0}^{\infty} f_{NOj}}{\delta x_3} + \frac{\rho}{s^\beta}\mathcal{L}[\frac{\delta^2\ (\sum_{j=0}^{\infty} f_{NOj}}{\delta {x^2}_1} + \frac{\delta^2\ (\sum_{j=0}^{\infty} f_{NOj}}{\delta {x^2}_2} + \frac{\delta^2\ (\sum_{j=0}^{\infty} f_{NOj}}{\delta {x^2}_3}]$$

$$\mathcal{L}(\sum_{j=0}^{\infty} v_{j+1}) = -\frac{1}{s^\beta}\mathcal{L}[(\sum_{j=0}^{\infty} f_{NO_2j})\frac{\delta(\sum_{j=0}^{\infty} f_{NO_2j}}{\delta x_1} + \sum_{j=0}^{\infty} f_{NO_2j})\frac{\delta(\sum_{j=0}^{\infty} f_{NO_2j}}{\delta x_2} + \sum_{j=0}^{\infty} f_{NO_2j})\frac{\delta(\sum_{j=0}^{\infty} f_{NO_2j}}{\delta x_3} + \frac{\rho}{s^\beta}\mathcal{L}[\frac{\delta^2\ (\sum_{j=0}^{\infty} f_{NO_2j}}{\delta {x^2}_1} + \frac{\delta^2\ (\sum_{j=0}^{\infty} f_{NO_2j}}{\delta {x^2}_2} + \frac{\delta^2\ (\sum_{j=0}^{\infty} f_{NO_2j}}{\delta {x^2}_3}]$$

$$\mathcal{L}(\sum_{j=0}^{\infty} w_{j+1}) = -\frac{1}{s^{\beta}}\mathcal{L}[(\sum_{j=0}^{\infty} f_{SO_2 j})\frac{\delta(\sum_{j=0}^{\infty} f_{SO_2 j}}{\delta x_1} + \sum_{j=0}^{\infty} f_{SO_2 j})\frac{\delta(\sum_{j=0}^{\infty} f_{SO_2 j}}{\delta x_2} + \sum_{j=0}^{\infty} f_{SO_2 j})\frac{\delta(\sum_{j=0}^{\infty} f_{SO_2 j}}{\delta x_3} + \frac{\rho}{s^{\beta}}\mathcal{L}[\frac{\delta^2\ (\sum_{j=0}^{\infty} f_{SO_2 j}}{\delta x^2{}_1} + \frac{\delta^2\ (\sum_{j=0}^{\infty} f_{SO_2 j}}{\delta x^2{}_2} + \frac{\delta^2\ (\sum_{j=0}^{\infty} f_{SO_2 j}}{\delta x^2{}_3}]$$

$$\mathcal{L}(\sum_{j=0}^{\infty} x_{j+1}) = -\frac{1}{s^{\beta}}\mathcal{L}[(\sum_{j=0}^{\infty} f_{O_3 j})\frac{\delta(\sum_{j=0}^{\infty} f_{O_3 j}}{\delta x_1} + \sum_{j=0}^{\infty} f_{O_3 j})\frac{\delta(\sum_{j=0}^{\infty} f_{O_3 j}}{\delta x_2} + \sum_{j=0}^{\infty} f_{O_3 j})\frac{\delta(\sum_{j=0}^{\infty} f_{O_3 j}}{\delta x_3} + \frac{\rho}{s^{\beta}}\mathcal{L}[\frac{\delta^2\ (\sum_{j=0}^{\infty} f_{O_3 j}}{\delta x^2{}_1} + \frac{\delta^2\ (\sum_{j=0}^{\infty} f_{O_3 j}}{\delta x^2{}_2} + \frac{\delta^2\ (\sum_{j=0}^{\infty} f_{O_3 j}}{\delta x^2{}_3}]$$

$$\mathcal{L}(\sum_{j=0}^{\infty} y_{j+1}) = -\frac{1}{s^{\beta}}\mathcal{L}[(\sum_{j=0}^{\infty} f_{pmj})\frac{\delta(\sum_{j=0}^{\infty} f_{pmj}}{\delta x_1} + \sum_{j=0}^{\infty} f_{pmj})\frac{\delta(\sum_{j=0}^{\infty} f_{pmj}}{\delta x_2} + \sum_{j=0}^{\infty} f_{pmj})\frac{\delta(\sum_{j=0}^{\infty} f_{pm}}{\delta x_3} + \frac{\rho}{s^{\beta}}\mathcal{L}[\frac{\delta^2\ (\sum_{j=0}^{\infty} f_{pmj}}{\delta x^2{}_1} + \frac{\delta^2\ (\sum_{j=0}^{\infty} f_{pmj}}{\delta x^2{}_2} + \frac{\delta^2\ (\sum_{j=0}^{\infty} f_{pmj}}{\delta x^2{}_3}]$$

$$\mathcal{L}(\sum_{j=0}^{\infty} z_{j+1}) = -\frac{1}{s^{\beta}}\mathcal{L}[(\sum_{j=0}^{\infty} f_{pbj})\frac{\delta(\sum_{j=0}^{\infty} f_{pbj}}{\delta x_1} + \sum_{j=0}^{\infty} f_{pbj})\frac{\delta(\sum_{j=0}^{\infty} f_{pbj}}{\delta x_2} + \sum_{j=0}^{\infty} f_{pbj})\frac{\delta(\sum_{j=0}^{\infty} f_{pb}}{\delta x_3} + \frac{\rho}{s^{\beta}}\mathcal{L}[\frac{\delta^2\ (\sum_{j=0}^{\infty} f_{pbj}}{\delta x^2{}_1} + \frac{\delta^2\ (\sum_{j=0}^{\infty} f_{pbj}}{\delta x^2{}_2} + \frac{\delta^2\ (\sum_{j=0}^{\infty} f_{pbj}}{\delta x^2{}_3}] \qquad (56)$$

The final model for forecasting the appropriate amount of contaminants in the atmosphere is Equation (56)

3. Results and discussion

The results used in this analysis were obtained from world health organization database. Different measures were put in place in the past in order to reduce these emissions. Solutions to improve air quality impact on health could include measures to discourage the use of biomass in small installations, or to increase the stringency of the emission limits in the Ecodesign Directive (Alimissis *et al*.,2018). Several literatures used damage cost approach, to analyse air pollution. Most of the calculations in literature includes damage costs for biomass use which was made in order to account for the public health impact. In terms of improving air quality and minimising the impact on public health, wood burning, if it were to be used at all, would be best deployed in large, efficient power stations rather than small-scale domestic. The results obtained showed that non-exhaust emissions of PM_{10}, and to a lesser extent $PM_{2.5}$, are projected to increase significantly by 2050 as traffic activity increases as compared with other results in literatures(Franck et al., 2011; Peled, 2011).Regional household emissions varied between 0.97.0.96,ozone varied between 60.9-30.7 for different regions in the world, $PM_{2.5}$ varied between (84μg/m^3)-(27μg/m^3)The precise agents in tyre and brake wear and resuspended dust responsible for the potential toxicity of these emissions are, as yet, unclear, so reformulation of these products would need to await more clarification from toxicological research. However, in the meantime, the obvious solution to ameliorate potential impact from all emissions from road transport here would be to discourage traffic use, particularly in urban centres. On the positive side, electrification of the road transport fleet results in large reductions in the potential adverse impact on health from NO_2 and potential compliance with legal standards. This will also have benefits for PM concentrations and will, to a limited degree, offset the impact of any continued increase in biomass use. The work has shown that trends in different fractions of the atmospheric particle mix may be different in future. Primary particles (containing known carcinogens) may increase, whereas secondary particles may decrease. This highlights the importance of studies to elucidate the differential toxicity of different particle fractions. The work has shown that, with increased penetration of ultra-low and zero-emissions road vehicles, concentrations of NO_2 will decrease by large amounts when compared with other results in literature (Franck et al., 2011; Peled, 2011). The precise role of NO_2, compared with that of $PM_{2.5}$ and other pollutants, in affecting human health is still uncertain. More clarity is needed here before any health benefits from reductions in NO_2 can be confidently quantified. The effects of long-term exposure to air pollution on mortality generally dominate cost–benefit analysis, but a full investigation of the health impact would involve quantifying the potential effects on a wider range of health outcomes.

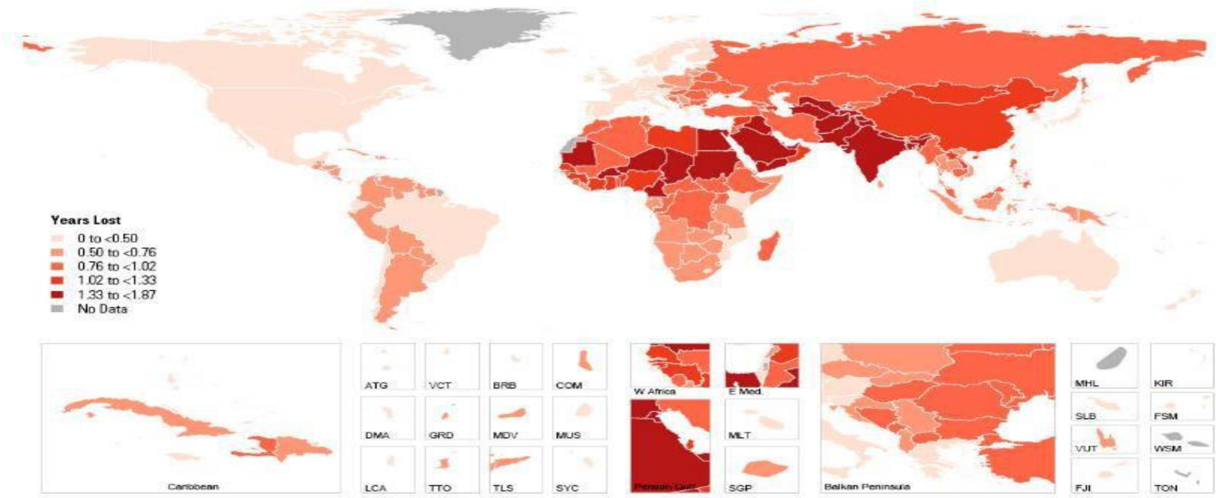

Fig. 5: Annual average $PM_{2.5}$ concentrations in 2017 relative to the WHO air quality guideline

Fig. 6: Population-weighted seasonal average (8-hour max) ozone concentrations in countries

Fig. 7: percentage of exposure to household emissions in some continents in the world

In 2017, large number of people were exposed to household pollution emissions. Globally, nearly half of the world's population were affected i.e., a total of 3.6billion people. India had 846 million people infected in 2017 (about 60% of the population). In china,452 million people were infected in 2017(32% of the population). In Bangladesh ,124 million people were infected (79% of the population). In democratic republic of congo,78 million people were infected (96% of the population).

4. Conclusions

The development of a new energy and air quality model has been a significant undertaking and represents an important step forward as a policy development tool. The inputs to the model system are numerous and the uncertainties are difficult to test in a comprehensive way. The results obtained showed that air pollution models is able to reproduce 2011 and 2012 concentrations of NO_X, NO_2, O_3, PM_{10} and $PM_{2.5}$ at spatial scales. Air pollution could be erased by letting citizens test their own air quality, growing an urban forest to clean the air, printing with inks made from polluted air, transforming smog into jewellery, cleaning the air with skyscrapers, introducing pollution vacuum cleaners, taking fossil fuels off the road for good, introducing trees in urban areas, setting the state for zero – emission vehicles, creating hydrogen fuel from air pollution, introducing air pollution sensors, smart streetlights and sensors, introducing anti-smog guns to shoot pollution down from the air and using google earth to track pollution in areas. Ongoing improvements in modelling of air pollution exposures, pollutants (beyond PM2.5) and disease outcomes, will further refine analyses. Specific examples include uncertainties in our understanding of PM_{10} non-exhaust emissions, which are assumed to increase pro rata with vehicle kilometres to 2050. This assumption may change as some private cars become lighter, are fitted with lower rolling resistant tyres and use regenerative braking, whereas delivery vehicles become heavier, and as all vehicles are subject to increased city congestion and there are ongoing changes to the materials used in brakes and tyre manufacture. Without regulation of these sources future predictions should be considered with caution. Furthermore, the treatment of domestic wood burning emissions makes assumptions regarding the mix of wood burning appliances resulting in a 19% reduction in PM emissions per kilogram of wood burnt, as a result of the introduction of stoves complying with emission limits in the Ecodesign Directive (53% reduction in PM emissions compared with existing wood burners) and large pelletised domestic appliances (93% reduction in PM emissions compared with existing wood burners). Finally, although there will always be uncertainty in future predictions, the research aims were to provide alternative future scenarios, pointing out the potential for undesirable air pollution impacts within climate change policy and accepting that a large range of outcomes are possible. Laplace Adomian decomposition and Navier stokes Modelling were used to predict pollution rates from different sources in the world, and this research justified its application.

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