Screening method for regulatory purposes in the Argentine Republic

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Abstract: This paper presents a comparison between the screening method in accordance with the requirements of the Argentine regulations and the detailed screening procedures recommended by the United States Environmental Protection Agency (US-EPA). Both methodologies are applied to different scenarios of point sources in rural and urban areas. The intercomparison between both screening estimations is evaluated by calculating the quantitative model performance measures included in the Model Validation Kit. The Argentine regulations are restrictive with respect to US-EPA requirements. This restriction is greater when the impact of the emissions from a single point source or from multiple equal sources is evaluated.

Keywords: air quality management, Argentine regulations, regulatory dispersion models, screening methods.

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1 Introduction

The atmospheric dispersion models, used to estimate air quality impacts, can be classified into two levels of sophistication. If the simple estimation techniques or screening models indicate that the source poses a potential air quality problem, then a second, more sophisticated, model should be applied (US-EPA, 1992). In Argentina, this philosophy has been adopted by the Electricity Regulatory Agency (ENRE, 1997) and by the Environmental Regulations of the Province of Buenos Aires (SPA, 1997). The first specifies the requirements for the atmospheric impact assessment of power plants' emissions in the country, and the second regulates the atmospheric impact assessment of stationary point source emissions in the province of Buenos Aires. In general, the methodology in the Argentine regulations, to be applied to the screening phase of the air quality impact assessment, follows the detailed screening analysis recommended by the United States Environmental Protection Agency (US-EPA, 1992) for point sources. However, there are some differences between the Argentine regulations and US-EPA requirements. In Argentina, until the beginning of the last decade atmospheric dispersion modelling was applied only by the scientific community in research work. However, since 1997, environmental local authorities encourage the use of atmospheric dispersion models in air quality impact assessments. In this way, the Argentine authorities regulated a screening method that can be used more widely than the US-EPA screening analysis. The Argentine screening requirements can be applied not only to a single stack but also to any combination of multiple point sources without restrictions. This is because one of the most important differences between Argentine and US-EPA screening methods is that multiple stack emissions must be treated individually and cannot be treated as one equivalent stack, as in the US-EPA SCREEN3 model. This paper presents a comparison between both methodologies and also a comparison of the estimations of the maximum ground-level concentration, and the distance at which it occurs both for single and multiple point source scenarios.

2 Particular features of the screening analysis in the Argentine regulations

In general, the Argentine regulations recommend that the US-EPA screening analysis should be followed. However it also includes some differences in the following areas:

2.1 Mixing height

The Argentine regulations are required to set the mixing height at 1 m above the plume height in neutral and unstable atmospheric conditions, with an unlimited mixing height in stable conditions.

In the US-EPA SCREEN3 model, a mechanically driven mixing height is estimated to provide a lower limit to the mixing height during neutral and unstable conditions. If the plume height is calculated to be above this mixing height value, then the mixing height is set at 1 m above the plume height. In stable conditions the mixing height is unlimited.

2.2 Wind speed and stability class combinations

The Argentine regulations require the estimation of air concentrations considering the same stability wind-speed conditions as US-EPA screening procedures, but also include wind speeds of 15.0 m/s and 20.0 m/s for class C.

2.3 Multiple point sources

According to the Argentine regulations, multiple point sources have to be considered as individual point sources. In this case, the screening analysis includes the running of the model considering the mixing heights associated with each stack for the different stability wind-speed combinations, in order to determine the worst-case scenario.

The US-EPA screening model cannot explicitly determine maximum impacts from multiple sources, except by merging emissions from multiple nearby stacks into a single 'representative' stack (US-EPA, 1992). This procedure is fine for sources that emit the same pollutant from several stacks with similar parameters and that are within a distance of 100 m of each other. The parameters from dissimilar stacks should be merged with caution. If the stacks are more than a distance of about 100 m apart, or if stack heights, volumetric flow rates, or stack gas exit temperatures differ by more than about 20%, the US-EPA states that the resulting concentration estimates due to the merged stack procedure may be unacceptably high.

2.4 Wind direction

The Argentine regulation requires that for multiple point sources the screening analysis needs to be repeated in each of the eight main wind directions (north, northeast, east, southeast, south, southwest, west and northwest) in order to find the worst-case scenario.

Variation of wind direction is not available for point sources in the screening analysis of the US-EPA SCREEN models.

2.5 Compliance with the National Ambient Air Quality Standard

While the US-EPA regulations require compliance with the National Ambient Air Quality Standard, the Argentine regulations require compliance with half the value of the Argentine Ambient Air Quality Standard. It is important to note, however, that the Ambient Air Quality Standards for the primary air pollutants are similar in both countries.

3 Comparison between the results of SCREEN3 and RGSONDE models

Although the compliance with half the value of the Argentine Ambient Air Quality Standard values suggest that Argentine regulations are more restrictive than US-EPA regulations, the different regulatory requirements of both screening methods may enhance or diminish the magnitude of this restriction.

The differences mentioned above highlight the need for a screening model, which includes the Argentine regulation requirements. We have developed the Rotating Grid Screening Model (RGSONDE) using some of the techniques included in the US-EPA SCREEN3 model and adapting the algorithms to meet the Argentine regulation requirements.

We calculate the maximum ground-level concentration (C_{max}), and the distance at which it occurs (X_{max}), for every stability wind-speed combination included in the screening analysis, using the RGSONDE and the SCREEN3 models. First we present the results of a test run in order to check our results against the SCREEN3 predictions.

3.1 Test run results

In the test run we verify that for a single point source located in rural and urban areas, the predictions of RGSONDE when running as SCREEN3, show a very good agreement with the SCREEN3 estimations. In this test we considered a stack height of 20 m, the stack gas exit temperature was 375 K, the stack gas volumetric flow rate was 42.21 m^3/s and the emission rate was 13 g/s. Table 1 summarizes the following statistical parameters (Hanna *et al.*, 1991; Olesen, 1995) calculated for RGSONDE estimations for the test run when compared with SCREEN3 predictions:

bias $= \overline{(C_{SCR} - C_{RGS})}$

normalized mean square error (nmse) $= \dfrac{\overline{(C_{SCR} - C_{RGS})^2}}{\overline{C_{SCR}} - \overline{C_{RGS}}}$

correlation coefficient (cor) $= \dfrac{\overline{\left(C_{SCR} - \overline{C_{SCR}}\right)\left(C_{RGS} - \overline{C_{RGS}}\right)}}{\sigma_{C_{SCR}}\ \sigma_{C_{RGS}}}$

fa2 is the fraction of data for which: $0.5 \le \dfrac{C_{RGS}}{C_{SCR}} \le 2.0$

fractional bias (fb) $= \dfrac{\overline{C_{SCR}} - \overline{C_{RGS}}}{0.5\left(\overline{C_{SCR}} + \overline{C_{RGS}}\right)}$

fractional variance (fs) $= \dfrac{\sigma_{C_{SCR}} - \sigma_{C_{RGS}}}{0.5\left(\sigma_{C_{SCR}} + \sigma_{C_{RGS}}\right)}$

where C_{SCR} is the SCREEN3 value and C_{RGS} is the RGSONDE value, the overbar indicates an average, and $\sigma_{C_{SCR}}$ and $\sigma_{C_{RGS}}$ are the standard deviations of SCREEN3 and RGSONDE estimated quantities, respectively.

The largest maximum ground-level concentration (C_{MAX}), and the distance at which it occurs [$X(C_{MAX})$], are also included in Table 1. Note the difference between C_{max} and C_{MAX}, and X_{max} and $X(C_{MAX})$. There is little variation in the values of $X(C_{MAX})$ because the RGSONDE model calculates the concentration values at fixed distances of 50 m (regulation requirement) while the SCREEN3 model search for the exact location of $X(C_{MAX})$. The differences in C_{MAX} are not significant.

Table 1 Statistical parameters calculated for the RGSONDE estimations of the maximum ground-level concentrations (C_{max}) and distance (X_{max}) for each wind-speed stability class combination when compared with SCREEN3 predictions. N is the number of estimations, other statistical parameters are defined in the text. C_{MAX} is the largest maximum ground-level concentration and $X(C_{MAX})$ is the distance at which C_{MAX} occurs.

Test run: Maximum ground-level concentration (mg/m^3)									
Rural area		(N = 47)							
model	mean	sigma	bias	nmse	cor	fa2	fb	fs	C_{MAX}
SCREEN3	0.05	0.02	----	----	----	----	----	----	0.085
RGSONDE	0.05	0.02	0.00	0.00	1.000	1.000	0.001	0.004	0.085
Urban area		(N = 43)							
SCREEN3	0.09	0.02	----	----	----	----	----	----	0.134
RGSONDE	0.09	0.02	0.00	0.00	0.999	1.000	0.005	0.019	0.134
Test run: Downwind distance to maximum ground-level concentration (m)									
Rural area		(N = 47)							
model	mean	sigma	bias	nmse	cor	fa2	fb	fs	$X(C_{MAX})$
SCREEN3	2090.32	1902.40	----	----	----	----	----	----	473
RGSONDE	2091.49	1905.40	–1.17	0.00	1.000	1.000	–0.001	–0.002	450
Urban area		(N = 43)							
SCREEN3	485.02	329.07	----	----	----	----	----	----	154
RGSONDE	484.88	328.59	0.14	0.00	0.999	1.000	0.000	0.001	150

In the following scenarios we compare the predictions obtained by applying the Argentine regulations (RGSONDE) with the results obtained using the US-EPA screening analysis (SCREEN3).

3.2 *Single point source (rural and urban areas)*

The maximum ground-level concentrations (C_{max}) calculated using the RGSONDE and SCREEN3 models, for a single point source located in rural and urban areas are shown in Figure 1. We considered the same single stack as used in the test run in order to see the differences between the results of both methods.

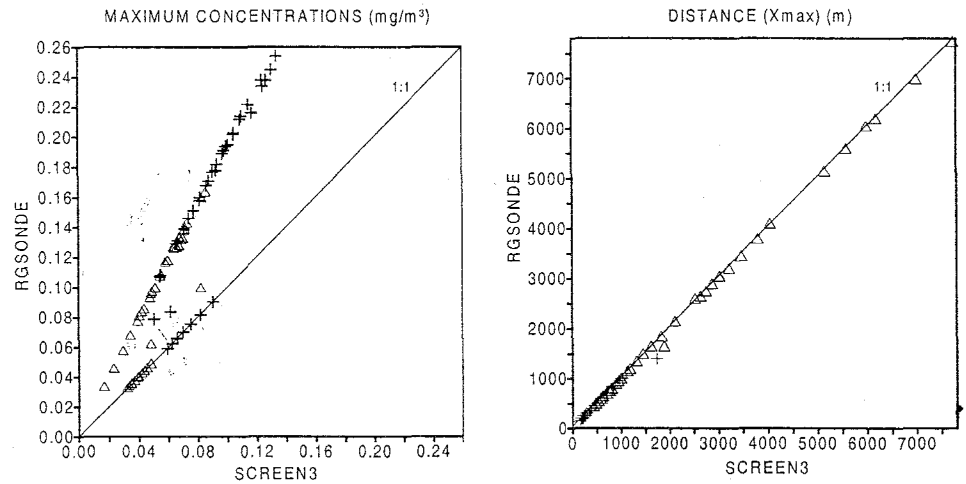

Figure 1 Comparison between RGSONDE and SCREEN3 estimates of ground-level concentration (left plot) and the downwind distance at which it occurs (right plot) for each stability wind-speed combination (•: rural; + urban). Estimates for a single stack.

The values on the 1:1 line in Figure 1 denote stable conditions (when both models assume unlimited mixing height). In neutral and unstable conditions RGSONDE gives more conservative values of C_{max} than SCREEN3. Setting the mixing height 1 m above the plume height in these atmospheric conditions causes the RGSONDE to give higher concentration values than SCREEN3. There is little difference between the estimated distance (X_{max}) given by both models.

The statistical parameters calculated for the RGSONDE estimations of C_{max} and X_{max} are given in Table 2, along with the largest value of maximum ground-level concentration (C_{MAX}) and the distance at which it occurs [$X(C_{MAX})$] estimated by both models.

3.3 *Multiple point sources (rural and urban areas)*

3.3.1 *Slightly different stacks*

We consider three slightly different sources emitting the same pollutant and located within 100 m of each other. The parameters of each stack are given in Table 3.

Table 2 Statistical parameters calculated for the RGSONDE estimations of the maximum ground-level concentrations (C_{max}) and distance (X_{max}) for each wind-speed stability class combination when compared with SCREEN3 predictions. N is the number of estimations, other statistical parameters are defined in the text. C_{MAX} is the largest maximum ground-level concentration and $X(C_{MAX})$ is the distance at which C_{MAX} occurs.

Single point source: Maximum ground-level concentration (mg/m^3)									
Rural area		(N = 47)							
model	mean	sigma	bias	nmse	cor	fa2	fb	fs	C_{MAX}
SCREEN3	0.05	0.02	----	----	----	----	----	----	0.085
RGSONDE	0.09	0.04	−0.04	0.46	0.904	0.979	−0.534	−0.852	0.163
Urban area		(N = 43)							
SCREEN3	0.09	0.02	----	----	----	----	----	----	0.134
RGSONDE	0.15	0.06	−0.07	0.45	0.900	1.000	−0.564	−0.851	0.254

Single point source: Downwind distance to maximum ground-level concentration (m)									
Rural area		(N = 47)							
model	mean	sigma	bias	nmse	cor	fa2	fb	fs	$X(C_{MAX})$
SCREEN3	2090.32	1902.40	----	----	----	----	----	----	473
RGSONDE	2103.19	1903.48	−12.87	0.00	1.000	1.000	−0.006	−0.001	500
Urban area		(N = 43)							
SCREEN3	485.02	329.07	----	----	----	----	----	----	154
RGSONDE	474.42	296.96	10.60	0.01	0.989	1.000	0.022	0.103	150

Table 3 Parameters of three slightly different sources located within 100 m of each other. Each stack emits the same pollutant. h_s is the stack height; T_s is the stack gas exit temperature; V is the stack gas volumetric flow rate; Q is the emission rate; x_s and y_s are the coordinates of the stack location; and M is the merged stack parameter, defined by $(h_s \times V \times T_s)/Q$.

Stack	h_s(m)	T_s (K)	V (m^3/s)	Q (g/s)	x_s(m)	y_s(m)	M
1	40	375	42.21	30.0	70.0	0.0	21 104
2	44	420	48.00	35.0	70.0	50.0	25 344
3	36	350	39.00	25.0	0.0	0.0	19 656

In Table 3, the merged stack parameter, M, accounts for the relative influence of stack height, plume rise and emission rate on concentration (US-EPA, 1992). According to US-EPA (1992) we consider the stack that has the lowest value of M as the 'representative' stack to use in SCREEN3 model runs.

The values of C_{max} and X_{max} obtained by RGSONDE compared with the estimations of SCREEN3 are shown in Figure 2. Table 4 presents the statistical parameters of the RGSONDE estimations when compared with SCREEN3. The maximum ground-level concentrations estimated by RGSONDE are smaller than the SCREEN3 estimations by approximately 17% and the distance X_{max} is, in general, greater by about 24%. Considering the worst-case scenario, the largest C_{max} predicted by RGSONDE for rural area is 11% less than the SCREEN3 prediction and for an urban area it is 13% less than the SCREEN3 prediction.

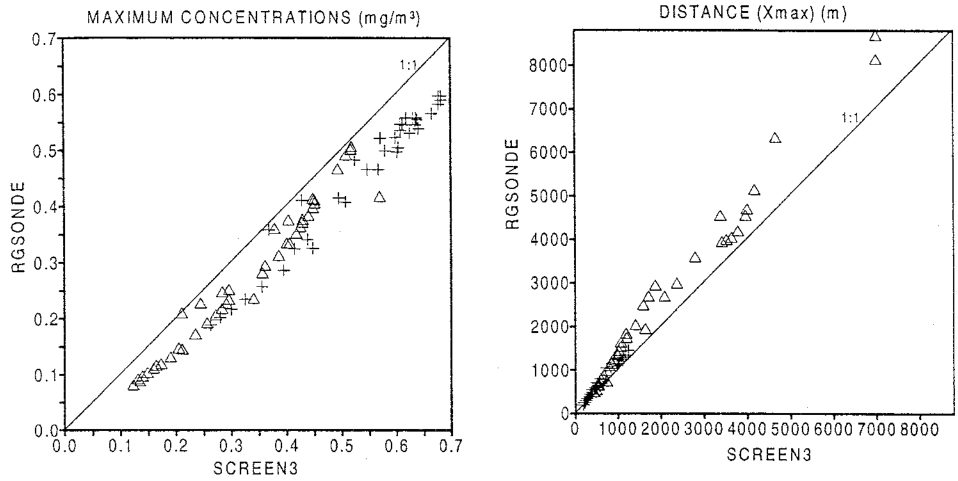

Figure 2 Comparison between RGSONDE and SCREEN3 ground-level concentration estimates (left plot) and downwind distance at which it occurs (right plot), for each stability wind-speed combination (•: rural; + urban). Estimates for three slightly different stacks.

Table 4 Statistical parameters calculated for the RGSONDE estimations of the maximum ground-level concentrations (C_{max}) and distance (X_{max}) for each wind-speed stability class combination when compared with SCREEN3 predictions. N is the number of estimations, other statistical parameters are defined in the text. C_{MAX} is the largest maximum ground-level concentration and $X(C_{MAX})$ is the distance at which C_{MAX} occurs.

Multiple point sources (slightly different stacks): Maximum ground-level concentration (mg/m^3)									
Rural area		($N = 44$)							
model	mean	sigma	bias	nmse	cor	fa2	fb	fs	C_{MAX}
SCREEN3	0.33	0.13	----	----	----	----	----	----	0.570
RGSONDE	0.28	0.13	0.05	0.04	0.980	1.000	0.170	0.000	0.507
Urban area		($N = 43$)							
SCREEN3	0.54	0.12	----	----	----	----	----	----	0.683
RGSONDE	0.46	0.12	0.08	0.03	0.982	1.000	0.162	–0.002	0.597
Multiple point sources (slightly different stacks): Downwind distance to maximum ground-level concentration (m)									
Rural area		($N = 44$)							
model	mean	sigma	bias	nmse	cor	fa2	fb	fs	$X(C_{MAX})$
SCREEN3	1897.41	1662.88	----	----	----	----	----	----	740
RGSONDE	2411.36	1984.57	–513.95	0.09	0.992	1.000	–0.239	–0.176	500
Urban area		($N = 43$)							
SCREEN3	471.74	316.28	----	----	----	----	----	----	266
RGSONDE	579.07	365.72	–107.33	0.06	0.992	1.000	–0.204	–0.145	300

3.3.2 Three equal stacks

We consider the following three stacks located within 100 m of each other. The parameters are given in Table 5.

Table 5 Parameters of three equal sources located within 100 m of each other. Each stack emits the same pollutant. The parameters are defined in Table 3.

Stack	h_s(m)	T_s (K)	V(m^3/s)	Q(g/s)	x_s(m)	y_s(m)	M
1	36	350	39.00	25.0	70.0	0.0	19 656
2	36	350	39.00	25.0	70.0	50.0	19 656
3	36	350	39.00	25.0	0.0	0.0	19 656

The comparisons of the maximum ground-level concentrations and X_{max} obtained by both models are shown in Figure 3. Although the three stacks and emission properties in this case are slightly different from those considered in the single stack run (see Section 3.2), the differences between Figure 1 and Figure 3 appears mainly because RGSONDE does not treat the three emissions as originating from a single representative stack. The maximum concentrations have a little more scatter in Figure 3 than in Figure 1 because of the different contributions of each stack to the maximum concentration.

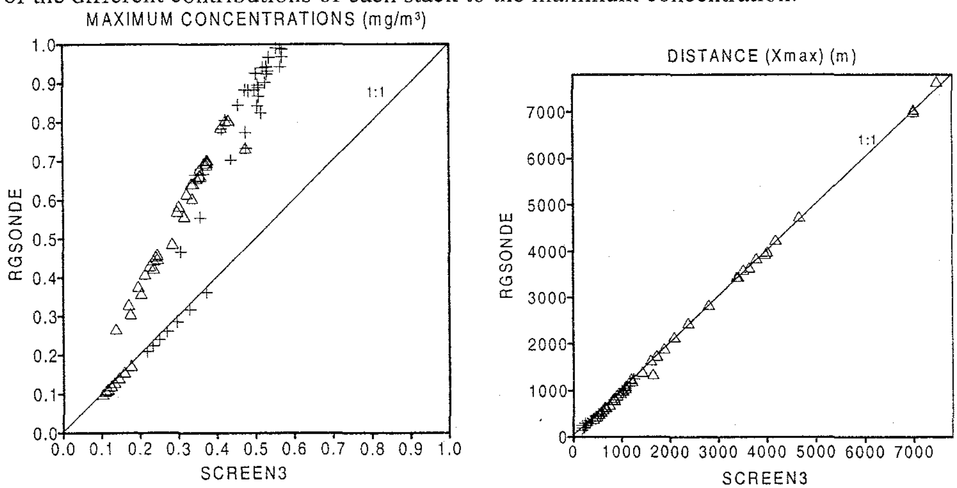

Figure 3 Comparison between RGSONDE and SCREEN3 ground-level concentration estimates (left plot) and downwind distance at which it occurs (right plot). Note that: • = rural; + = urban. Estimates for three equal stacks.

Table 6 presents the statistical parameters of the RGSONDE estimations compared with SCREEN3 for three equal stacks.

The estimations of RGSONDE are greater than the values given by SCREEN3 by approximately 70% and the X_{max} values differ by less than 10%. The limited mixing height (1 m above the plume rise) strongly reduces the vertical dispersion of the emissions from the three sources.

For the worst-case scenario, the RGSONDE prediction of C_{MAX} in a rural area is 70% greater than the value estimated by SCREEN3 and in an urban area it is 74% greater than the SCREEN3 value.

Table 6 Statistical parameters calculated for the RGSONDE estimations of the maximum ground-level concentrations (C_{max}) and distance (X_{max}) for each wind-speed stability class combination when compared with SCREEN3 predictions. N is the number of estimations, other statistical parameters are defined in the text. C_{MAX} is the largest maximum ground-level concentration and $X(C_{MAX})$ is the distance at which C_{MAX} occurs.

Multiple point sources (three equal stacks): Maximum ground-level concentration (mg/m^3)									
Rural area		($N = 45$)							
model	mean	sigma	bias	nmse	cor	fa2	fb	fs	C_{MAX}
SCREEN3	0.27	0.11	----	----	----	----	----	----	0.475
RGSONDE	0.48	0.23	−0.21	0.46	0.980	1.000	−0.552	−0.739	0.806
Urban area		($N = 43$)							
SCREEN3	0.45	0.10	----	----	----	----	----	----	0.569
RGSONDE	0.75	0.24	−0.30	0.34	0.950	1.000	−0.505	−0.841	0.990

Multiple point sources (three equal stacks): Downwind distance to maximum ground-level concentration (m)									
Rural area		($N = 45$)							
model	mean	sigma	bias	nmse	cor	fa2	fb	fs	$X(C_{MAX})$
SCREEN3	2021.20	1837.93	----	----	----	----	----	----	740
RGSONDE	2029.00	1868.94	−7.80	0.00	1.000	1.000	−0.004	−0.017	450
Urban area		($N = 43$)							
SCREEN3	471.74	316.28	----	----	----	----	----	----	266
RGSONDE	458.44	314.20	13.30	0.01	0.995	1.000	0.029	0.007	300

4 Conclusions

In the Argentine Republic there are two regulations that determine the air quality modelling technique that should be applied to revisions for existing sources, and to new source reviews. One concerns the emissions from power plants in the country and the other to stationary point sources located in the province of Buenos Aires. In general, the Argentine regulations are in compliance with the US-EPA SCREEN3 recommendations but introduce some different requirements in the screening procedures. The model RGSONDE follows the Argentine recommendations. The maximum ground-level concentrations predicted by RGSONDE are greater than the SCREEN3 results by more than 70% when studying the air quality impact of a single point source or multiple equal sources. If the stacks are slightly different, RGSONDE maximum concentrations are less than SCREEN3 predictions by 12%. According to these results and bearing in mind that the Argentine regulations require comparison of the total maximum ground-level concentrations (calculated C_{MAX} plus background concentration) with half the Air Quality Standard, the Argentine regulations are restrictive with respect to the US-EPA requirements. This restriction is greater when the air quality impact of the emissions from a single point source or from multiple equal sources is evaluated.

The scenario of several dissimilar stacks could not be analysed because the US-EPA screening procedures is not recommended in this case.

5 Acknowledgements

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