Journal of the University of Chemical Technology and Metallurgy, 43, 2, 2008, 227-230

CALCULATING THE SALT INDEX OF PK AND NPK LIQUID FERTILIZERS FROM POTASSIUM PHOSPHATES

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Received 17 December 2007
Accepted 25 January 2008

ABSTRACT

Potassium phosphates (PK) possess certain characteristics that make them very attractive as fertilizer constituents. In comparison with most conventional fertilizers, potassium phosphates have a low salt index (SI). The salt index is defined as the ratio of the increase in osmotic pressure of the soil solution produced by the fertilizer to that produced by the same mass of sodium nitrate. Generally speaking the lower the SI of a fertilizer the less it tends to inhibit seed germination and sprouting, or causes scorching. The index is useful in selecting or formulating fertilizers for special placements in or near the seed.

Hardesty [1] and Mortvedt [2] have shown how the salt index of compound fertilizers can be calculated from their formulation. Unfortunately their method can not be applied for calculation the salt index of PK fertilizer produced from H_3PO_4 *and KOH instead of missing of data for SI of KOH.*

The problem was solved by converting the ratio between KOH and H_3PO_4 *as a ratio between their products* KH_2PO_4 *and* K_2HPO_4 *with known SI values.*

Two examples for calculation of SI of different formulations are given. NPK liquid fertilizers on the base of potassium phosphates and organic nitrogen have the lowest SI value comparing with other complex liquid fertilizers.

Keywords: salt index, liquid fertilizers, potassium phosphates.

INTRODUCTION

The salt index of fertilizers is an index of the extent to which a given amount of various fertilizers increases the osmotic pressure of a soil solution. The index was developed by Rader et al. [3] and was defined as “the ratio of the increase in osmotic pressure produced by the fertilizer material to that produced by the same mass of $NaNO_3$ and to give whole numbers, multiplied by 100”. Salt index values of the most common fertilizers are given in Table 1.

The index is useful in selecting or formulating fertilizers for special placement in or near the seed. The salt index does not predict the exact amount of a fertilizer that could produce crop injures on a particular soil, but it does classify the fertilizer with respect to others as regards osmotic effect and shows which fertilizers will be most likely to injure crops. Dealers or growers then can select those formulations with lower SI values that best fit their needs.

The osmotic pressure of fertilizer solutions for foliar application is also of interest, but in this case the solution is not in contact with the soil. Therefore, the salt index, as determined by Rader, is not quantitatively useful for determining the suitability of a solution for foliar application. Direct measurement of the osmotic pressure of water solutions would be more suitable for this purpose.

In addition, injury to crops can be caused by effects other than salt concentration [2]. For instance, some fertilizers such as urea, UAN, diammonium phosphate or ammonium thiosulphate can produce free ammonia (NH_3) under certain soil conditions which may have a phytotoxic effect (poor germination or seedling death). Selection of the proper fertilizer is the way to minimize this occurrence.

Fertilizers best suited for a seed row application have 1) a low salt index, 2) high water solubility, 3) contain N,P,K and S, with relatively high P content , 4) contain both urea and ammonium nitrogen, 5) minimize the content of compounds that liberate NH_3, and 6) use potassium phosphates instead of KCl , KNO_3 and K_2SO_4 as the K source.

Fluid fertilizers may produce a lower osmotic pressure in the soil solution than granular products of similar grade. Fewer problems generally are encountered using fluids as seed – row fertilizers when compared to granular, since less soil water is required and salts are mainly dissolved in fluid formulations.

In comparison with most conventional fertilizers, potassium phosphates have a low salt index (SI) (see Table 1).

The solubility of the mixture of KH_2PO_4 and K_2HPO_4 is very high [4] and this makes them very attractive as liquid fertilizers for foliar and root feeding of the plants.

RESULTS AND DISCUSSION

The most obvious method for obtaining potassium phosphates – by the reaction of phosphoric acid with caustic potash – has been used for producing detergent – grade phosphates and speciality (e.g. foliar) fertilizers. According to Mortvedt [2] and Hardesty [1]

Table 1. Salt index values of the most common fertilizer materials.

Material, formula and analysis	Total primary plant nutrients, %	Salt index*	Adjusted salt index**
Nitrogen/Sulphur sources			
Natural organic, 13 % N	13	3.5	26.9
Ammonia, NH_3, 82.2 % N	82.2	47.1	57.3
Ammonium nitrate, NH_4NO_3, 35 % N	35	104.7	299.1
Urea, $CO(NH_2)_2$, 46.6 % N	46.6	75.4	161.8
UAN (44 % NH_4NO_3, 35 % $CO(NH_2)_2$, 21 %H_2O), 32 % N	32	71.1	222.2
Ammonium sulphate, $(NH_4)_2SO_4$, 21.2 % N, 24.3 % S	21.2	69.0	325.5
Ammonium thiosulphate $(NH_4)_2S_2O_3$, 12 % N, 26 % S	12	90.4	753.3
Phosphorus sources			
Normal superphosphate, $Ca(H_2PO_4)_2.2CaSO_4$, 20 % P_2O_5	20	7.8	39.0
Triple superphosphate, $Ca(H_2PO_4)_2$, 45 % P_2O_5	45	10.1	22.4
Potassium/ Sulphur sources			
Potassium chloride, KCl, 63.2 % K_2O	63.2	114.3	180.8
Potassium sulfate, K_2SO_4, 54 % K_2O, 18.4 % S	54	46.0	85.2
Potassium thiosulfate, $K_2S_2O_3$, 49.5% K_2O, 33.7 % S	49.5	136	274.7
NP sources			
Ammonium dihydrogen phosphate, $NH_4H_2PO_4$, 12.2 % N, 61.7 % P_2O_5	73.9	29.9	40.5
Diammonium hydrogen phosphate, $(NH_4)_2HPO_4$, 21.2% N, 53.7 % P_2O_5	74.9	34.2	45.6
NK sources			
Potassium nitrate, KNO_3, 13.8 % N, 46.6 % K_2O	60.4	73.6	121.8
PK sources			
Potassium dihydrogen phosphate, KH_2PO_4, 52.2 % P_2O_5, 34.6 % K_2O	86.8	8.4	9.7
Dipotassium hydrogen phosphate, K_2HPO_4,, 40.8 % P_2O_5, 54 % K_2O	94.8	17.4	18.4

*Salt index – per equal masses of materials

** Adjusted salt index – per unit (20 lbs) of primary plant nutrients

Table 2. Salt index values of solid mixtures (KH_2PO_4 + K_2HPO_4).

Mass ratio $\frac{\omega(K_2O)}{\omega(P_2O_5)}$	Mass parts of the components, % $\omega(KH_2PO_4)$	$\omega(K_2HPO_4)$	Plant nutrient, % $\omega(P_2O_5)$	$\omega(K_2O)$	Total plant nutrient, % $\omega(P_2O_5+K_2O)$	Salt Index (SI)	Adjusted salt index (ASI)
0.663	100	-	52.15	34.61	86.76	8.4	9.7
0.7	93.12	6.88	51.36	35.94	87.30	9.0	10.3
0.8	75.13	24.87	49.30	39.18	88.48	10.6	12.0
0.9	58.56	41.44	47.42	42.67	90.09	12.1	13.4
1.0	43.18	56.82	45.66	45.66	91.32	13.5	14.8
1.1	28.93	71.07	44.04	48.44	92.48	14.8	16.0
1.2	15.63	84.37	42.53	51.04	93.57	16.0	17.1
1.3	3.24	96.76	41.11	53.44	94.55	17.1	18.1
1.327	-	100	40.75	54.08	94.83	17.4	18.4

the SI per ton of a dry – mixed or liquid formulation containing N, P and/or K is obtained by multiplying the adjusted salt index of plant nutrients (last column in Table 1) by the total number of units which the respective material supplies in the mixture (solution) and adding the resulting values. Because of missing data for SI of KOH it is not possible to calculate the salt index of the respective PK liquid fertilizers produced from H_3PO_4 and KOH in this way. However, there are data for SI of the products KH_2PO_4 and K_2HPO_4 (see Table 1). The solving of the problem is to convert the ratio between KOH and H_3PO_4 (respectively, between K_2O and P_2O_5) as a ratio between their products KH_2PO_4 and K_2HPO_4. This was done (see Table 2) - the plot is given on Fig. 1.

The salt index and adjusted salt index of PK fertilizers (mixture of KH_2PO_4 and K_2HPO_4) with different ratios $\omega(K_2O)/\omega(P_2O_5)$, are calculated by the equations:

$$SI(PK)=SI(KH_2PO_4)\omega(KH_2PO_4)+ + SI(K_2HPO_4)\omega(K_2HPO_4) \quad (1)$$

$$SI(PK)= 8.4\,\omega(KH_2PO_4) + 17.4\,\omega(K_2HPO_4) \quad (2)$$

$$ASI(PK)=\frac{SI(PK)}{\omega(P_2O_5+K_2O)} \quad (3)$$

where: *SI(PK)* and *ASI(PK)* – salt index and adjusted salt index of the mixture (KH_2PO_4+ K_2HPO_4); $\omega(P_2O_5+K_2O)$ – mass part of total plant nutrients in the mixture.

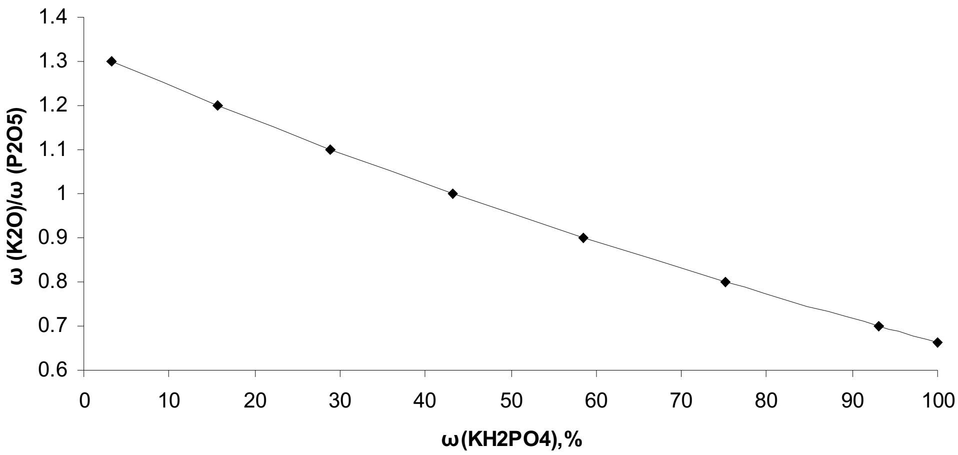

Fig. 1. Dependence of the mass ratio $\omega(K_2O)\,\omega(P_2O_5)$ on the composition of the mixture (KH_2PO_4 + K_2HPO_4).

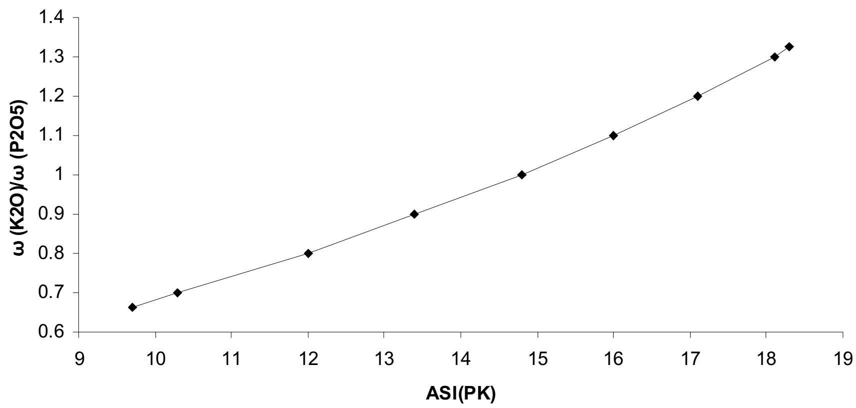

Fig. 2. Mass ratio ù(K_2O)/ù(P_2O_5) and the adjusted salt index of the mixture (KH_2PO_4 + K_2HPO_4)

The data are given in Table 2 and the dependence of ASI (PK) from the mass ratio $\omega(K_2O)/\omega(P_2O_5)$ is plotted on Figure 2. The adjusted salt index (PK) for a given $\omega(K_2O)/\omega(P_2O_5)$ ratio is constant and does not depend on the concentration of P_2O_5 and K_2O in the mixture (solid or liquid).

Therefore SI for fertilizers with known concentration of P_2O_5 and K_2O can be simply calculated by the equation:

$$SI(PK)= ASI(PK)\omega(P_2O_5+K_2O) \quad (4)$$

Example: Calculate the salt index of the liquid formulation 0 – 20 – 20, produced by H_3PO_4 and KOH.

$\omega(P_2O_5+K_2O)$ = 20+20 = 40 %, or 0.4 mass parts.

$\omega(K_2O)/\omega(P_2O_5)$ = 1, consequently, ASI (PK) = 14.8 (see Fig. 2)

SI (PK) = 14.8x0.4 = 5.9.

The salt index of NPK liquid fertilizers produced on the basis of potassium phosphates (H_3PO_4+ KOH) and nitrogen fertilizer/s can be calculated by the equation:

$$SI(NPK) = ASI(PK)\ \omega(P_2O_5+K_2O) + ASI(N)\omega(N) \quad (5)$$

where: *ASI(N)* – the adjusted salt index of the nitrogen fertilizer/s;

$\omega(N)$ and $\omega\ (P_2O_5+K_2O)$ – mass parts of the respective nutrients in the NPK liquid fertilizer.

Example: Calculate the salt index of the NPK liquid fertilizer of grade 10 – 10 – 10, produced by H_3PO_4, KOH and urea.

$\omega(N)$ = 10%, or 0.1 mass parts,

$\omega(P_2O_5+K_2O)$ = 10 + 10 = 20 % or 0.2 mass parts.

ASI (N) = 161.8 (see Table 1)

$\omega(K_2O)/\omega(P_2O_5)$=1, consequently *ASI(PK)* = 14.8 (see Fig. 2)

SI(NPK) = 14.8x0.2 + 161.8x0.1 = 2.96 + 16.18 = 19.1

The salt index for the same formulation (10 – 10 – 10) if instead of urea natural organic nitrogen is used will be:

SI(NPK) = 14.8x0.2 + 26.9x0.1 = 5.6

The results show that SI of fluid fertilizers varies significantly depending on the grade and components in the formulation.

CONCLUSIONS

The choice of materials having a low salt index is important in the manufacture of present – day high – analysis mixtures, especially for localized placement.

PK and NPK liquid fertilizers on the basis of potassium phosphates and organic nitrogen have the lowest SI value in comparison with the other complex liquid fertilizers.

Recommendations for fertilizer placement in direct seed contact vary with crop. Crop tolerance to increased osmotic pressure (salt content) of the soil solution in the vicinity of the seed varies considerably.

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