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Review

Salt Addition and Hazard by Water and Potash Fertilizers

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ABSTRACT

Potash use in Pakistan is very low. One of the reasons of this low usage is escalating farm input prices. MOP is a cheaper source of potash compared to SOP but its use is argued considering chloride accumulation in soil. Infact salt addition through MOP or SOP is little compared to what comes with irrigation water. Pakistan has one of the largest irrigation system in the world. Fresh water, even of best quality, brings considerable amounts of salts with it. Addition through tube well water is even higher. Salts added by all sources move in the soil profile depending upon amount of water passing below root zone. Initial movement of solutes in soil is vertical unless they reach the saturated zone. Then they may move laterally depending upon relief and natural gradient. In wheat-rice and sugarcane-wheat rotations salts might leach down to ground water but in wheat-cotton rotation those may stay in soil profile @ depth of 1.5 - 2 m unless heavy showers of Mon Soon push them further down. Similar is the fate of chloride and sulphate ions coming from K fertilizers. Both chloride and sulphate associated with K fertilizers do not seem to have potential salinity or toxicity hazard. However,, salt addition from different sources is greater than removal. This makes salt balance equation positive for the country. Only the canal water adds 24 million tones of salts in Indus basin annually which may harm our natural resources in future.

Key Words: Salts; Irrigation water; MOP; SOP; Salt movement; Soil profile

INTRODUCTION

Potassium is an essential element. Its role in plant nutrition is well established. However, its use in Pakistan is very low. In year 1999-2000 total potash use in the country was only 18 thousand tones compared to 2218 and 597 thousand tones of Nitrogen and Phosphorus, respectively (NFDC, 2000). This leads to poor NPK ratio which is among the lowest in the world. (Table I)

Fertilizer use in Pakistan is imbalanced and biased towards N. This is not only hurting yields but also impairing produce quality especially incase of fruits and vegetables. Low sugar recovery of sugarcane is another area of concern which may be improved with K use.

Table I. NPK ratio in some selected countries

Country	N	P_2O_5	K_2O
Egypt	6.73	1.00	0.30
Mexico	4.25	1.00	0.56
USA	2.86	1.00	1.15
Brazil	0.85	1.00	1.15
China	2.70	1.00	0.37
India	2.42	1.00	0.35
Korea (S)	2.38	1.00	1.12
Malaysia	1.72	1.00	2.77
Pakistan	3.72	1.00	0.03
Thailand	2.55	1.00	0.67
Turkey	2.33	1.00	0.13
UK	4.00	1.00	1.30
WORLD	2.54	1.00	0.66

(Anonymous, 2002)

Potash use around the globe is mainly in two forms i.e. MOP and SOP. The NPK fertilizers are also produced using MOP or SOP as raw material. Considering the straight sources MOP has a very dominant share of 93.4% compared to 4.7% of SOP in the world. However, in India MOP usage is 99.1% compared to 0.9% of SOP (Anonymous, 2002). MOP is not only a high grade fertilizer (60% K_2O) but is also cheaper than SOP. Use of SOP makes economic sense if sulphur fertilization is required, but the fact is that response to sulphur was insignificant in a long term experiment during 1985-91 (NFDC, 1994). Even at sites in barani tract where soil sulphur was suspected low, sulphur fertilization failed to increase yield of wheat crop in a four years long study (NFDC, 1994). So at present economics of both fertilizers is to be evaluated on basis of K contents.

In Pakistan both MOP and SOP are being used as K fertilizers but still there are concerns from few corners about MOP especially regarding the chloride addition which is doubted to contaminate the root zone or soil profile.

Salt addition with K fertilizers. Both potassic fertilizers are inorganic and have anions associated with K in the molecules. In fact rating of these fertilizers is being done on the basis of these anions. The fear of salt injury due to anion is the main concern. The recommended dose of potassium to various crops varies from 60 to 120 kg K_2O per hectare where as in most cases it is 60 kg K_2O per hectare (NFDC, 1998).

Balance sheet for anions. In a long term experiment of 15 years under wheat-maize fodder rotation researchers studied chloride hazard of MOP usage at AARI. They worked out a net chloride addition of 28 kg year^{-1} ha^{-1}. They did not calculate SO_4^{--} balance sheet but based on work of other sources it is believed that there is net addition of sulphate as well with use of SOP.

Some authors have reported even smaller sulphur uptake by corn plant (Sprague *et al.,* 1988) but the point to make is that maize plant can not remove all applied sulphur as SOP. So it is evident that in both cases there is net addition of salts and considering these small quantities there is possibility that both anions are likely to produce similar osmotic potential in the soil solution. Certainly, chloride has a high salt index, which is a measure of salt solubility, and will be of importance at relatively higher concentrations considering solubility of potassium sulphate and chloride salts. With quantity of 20-30 kg per ha Salt index should not be of practical significance from salinity point of view. However, high solubility of MOP will bring K in to solution readily and help earlier removal of Cl^- ions from root zone since its dissolution is high even at lower temperature (IPI, 2001).

As far as specific ion effect is concerned both sulhpate and chloride has wide critical limits. Even considering sensitive crop like citrus critical limit for chloride in soil varies from 20-50 meL^{-1}. This limit is up to 80 meL^{-1} for grapes (Skaggs *et al*., 1999). Assuming zero leaching and no crop removal addition of MOP @ 100 kg K_2O per ha would not contribute more than 15 meL^{-1} Cl^- for a soil having 35% saturation percentage.

This addition of 20-30 kg salts from fertilizer appears to be insignificant when we consider quantum of salts coming through irrigation water.

Water as salt carrier. Irrigation water, even of best quality, brings large amounts of salts in it. A water of EC 0.4 dSm- would add 2782 kg salt yr^{-1} ha^{-1} in wheat-cotton rotation. This much of salts can raise EC of 60 cm layer of soil to 4 dSm^{-1} when saturation percentage is 25. The addition through tube well water is much higher than this estimate. On country basis only Indus River System is known to bring 33 Million Tons of salts per annum (Shams ul Mulk, 1993).

Considering anions associated with K fertilizers canal water on an average adds 36 to 135 kg SO_4^{--} per hectare for our major crops, where as addition from tube well is higher and a water of EC 1.0 is likely to add 120 kg SO_4^{--} ha^{-1} yr^{-1} in just four irrigations (NFDC, 1994).

Similar is the case with chloride. Considering average concentration of 20 ppm Cl^- (Nabhan *et al*., 1989) canal water will add 214 kg Cl^- yr^{-1} ha^{-1} in wheat-cotton rotation, 1100 mm irrigation water. Where as tube well water having 71 ppm Cl^- will add 281 kg Cl^- ha$^-$ yr$^-$ in four irrigations. It is worth mentioning that in irrigation water Cl^- contents of less than 153 ppm (4.3 meL$^-$) are unlikely to affect crop health of like orange plants (IPI, 2001).

So it is quite clear that amounts of salts added through fertilizer are negligible compared to addition through irrigation water. Huge quantum of salts comes with water.

Fate of salts in soil. It has already been discussed that if salts added through different sources stay in the root zone, then agriculture can no longer sustain. Despite addition through irrigation water there are sources like fertilizers, mineral dissolution, capillary rise from ground water and rain water. However, some authors believe that upward movement of salts is small in non water logged conditions while salts precipitation coupled with crop removal can take care of mineral dissolution and addition through rain and fertilizers (Skaggs *et al*., 1999). We also have met similar finding in our case study discussed above. So effectively it is addition through irrigation water which really matters. There must be a sink for these salts. In soil a lot depends upon leaching fraction and soil drainage properties.

In a long term study spread over 34 years movement of chloride tracer was observed in semi arid Vadose zone of Canada. Wheat and barely crops were grown *(CI = 100%)* under rain fed condition when total annual precipitation was 321.4 mm *(CV 64.2%)* and growth season precipitation was only 189.1 mm. Small amount of 133.4 mm rain came in time when crop growth and evapotranspiration demands were low. Certainly effective rainfall in all cases will be lower than given numbers. The KCl application rate varied from 0.11 to 3.36 kg m^{-2}. The scientists observed a very rapid movement of chloride in first four years when the tracer traveled a mean distance of 1.34 m. Then there was a very slow movement for next 30 years and tracer covered a mean distance of 1.68 m after 34 years. The tracer stayed just at the bottom or below the root zone due to very low deep drainage of 3 mm year^{-1}. It appeared that crop evapotranspiration did not allow water to percolate deep during growth period instead it extracted water stored below root zone, through capillary action, which caused upward movement of tracer. There was some deep percolation during fallow period and some of tracers moved down to a depth of 6 m but amount of water passing through root zone was not enough to move all the tracers to deeper horizon. (Dyck *et al*., 2003).

In Australia chlorides accumulated at a depth of 7m in soil of Eucalyptus plantation where total annual precipitation was 800 mm. The downward velocity of soil solution was 0.3 mm yr^{-1}. Again not enough water infiltration to support further down ward movement (Skaggs *et al*., 1999).

In USA workers tried to measure nitrate leaching in corn fields when seasonal irrigation was 700 mm and effective rainfall was 210 mm. The evapotranspiration losses were estimated to be 790 mm. With 120 mm of water passing through root zone they measured NO^{-3} concentration of 10, 49 and 160 mg N L^{-1} at 2 m depth for application rates of 23, 57 and 262 kg N ha^{-1}. This represents a fast movement through root zone although deep percolation studies were not involved (Skaggs *et al.,* 1999).

In another example in deep alluvial fills of California, a nematocide chemical DBCP (1,2- dibromo-3-chloropropane) was used extensively from about mid 1950s to 1977, when it was banned. Yet DBCP was not detected in ground water for decades but in 1980's problem started and by 1986 about 86% of 3000 wells were contaminated and 44 out of 240 drinking water wells were closed since DBCP had exceeded maximum contaminant level. The DBCP is a stable compound with half life of 43 years. Movement of DBCP may not be assumed faster like anions since it had retardation effect due to its tendency of sorption on coarse textured material. With a deep percolation of 255 mm yr^{-1} through irrigation and rainfall it took 14 years to touch ground water covering a distance of 30 m. The peak DBCP levels in ground water reached after 31 years and is likely to decrease there after. Once the chemical reached the saturated zone, its lateral movement started. They estimated a time of 13.8 years to reach a well at distance of 1.6 Km down stream. This comes to travel of around 119 m per year (Skaggs *et al*., 1999).

Similar trend was observed by Hussain *et al.* (2002) at Pindi Bhattian, Pakistan where solutes resulting from applied soil amendments leached down to ground water and then moved laterally. They grew rice during kharif season and area received 499 mm rain during growth period. The lateral movement in this case was quite fast and seemed to be depression focused.

In some earlier studies it was investigated that salt accumulation below 60 cm does not cause drastic yield reductions. Salt accumulation of 14, 30 and 45 tones ha^{-1} in the lower portions of soil profiles having 0.6, 1.2 and 1.8 m depth caused yield reduction of less than 25% for alfalfa crop. Its the upper portion of root zone which matter (Skaggs *et al*., 1999).

So the finding is that there is vertical movement of solutes, chemicals depending upon amount of water passing through the root zone, soil drainage properties and solute properties itself. Water will percolate to deeper aquifer or carry salts, pesticides with it if not obstructed by impermeable layer. Once solutes/chemicals reach the saturated zone, then their lateral movement starts depending upon soil gradient and relief. In case deep percolation is not enough to drive salts through the soil profile, then they stay in the profile just at bottom or below root zone depending on amount of water moving through root zone. This means we should be analyzing water equations for our major crops to assess how much water is available for percolation. This will indicate likely fate of added salts.

Water equation for major rotations. In Pakistan there are four major crops which cover 65% of the cropped area (Agri. Statistics, 2003). These crops are wheat, rice, cotton and sugarcane. In fact these crops form three crop rotations, i.e. wheat-rice, sugarcane-wheat, wheat-cotton

Wheat rice rotation. The annual water requirement for this rotation is 2000 mm (OFWM, 1997). The mean evapotranspiration for this rotation in rice growing area of Punjab province is 980 mm per annum. In Sindh province, the mean ET for this rotation is 1713 mm (Ullah *et al*., 2001). This average annual rain fall of rice growing area in Punjab is 350-1000 mm while it is <125 mm for Sindh (khan *et al*., 2000). So there is strong possibility that solutes should reach the aquifer in this rotation when minimum of 300 mm water is likely to infilter through the root zone where as percolation in Punjab may be higher than the estimate.

Table II. Anions Balance Sheet

	All units in kg yr^{-1} ha^{-1}	
	MOP	**SOP**
K_2O Dose	120	120
Cl^- addition	95	
SO_4^{--} addition		123
Crop uptake of Cl^-/SO_4^{--}	67	99*
Net addition of Cl^-/SO_4^{--}	28	24

* Assuming 23.7% dry matter in maize fodder (Shah *et al.*, 1994) and 0.16% S content in maize fodder (Tandon, 2004); Wheat S uptake assumed 4.7 kg per Ton of produce (NFDC, 1996; Tandon, 2004)

Sugarcane Wheat Rotation. The average annual water requirement for this rotation is 2100 mm. The September sown cane is a year long crop and has water requirements of 2400 mm (OFWM, 1997). The mean ET for this rotation in Punjab is 1794 mm per annum (PARC, 1982). This area also receives annual rain fall of <250-600 mm annually (khan *et al*., 2000). In Sindh, major chunk of sugarcane is September sown and may have ET up to 1887 mm (Ullah *et al.*, 2001). This area also receives around 100-250 mm rainfall annually (Khan *et al*., 2000). This rotation is similar to rice wheat system where solutes might deep percolate to ground water when +200 mm water is likely to pass through the root zone where as percolation may be slightly higher for September sown cane.

Wheat cotton rotation. The average annual water requirement for this rotation is 1200 mm (OFWM, 1997). The mean ET for this rotation in Punjab and Sindh is 992 and 1279 mm, respectively (PARC, 1982) The average annual rainfall is < 250 mm in Punjab and 100-150 mm in Sindh for cotton growing areas (Khan *et al*., 2000). Under these conditions solutes may not leach deep in to saturated zone and accumulate at bottom or just below root zone as was in case study of Vadose region of Canada (Dyck *et al*., 2003). The only flux which can help downward movement of salts seem to be occasional heavy monsoon showers.

From the above discussion it appears that salt accumulation may take place in soil profile of area following wheat-cotton rotation. The crops may not get damaged in short term due to fair thickness of soil profile in Pakistan. But the real concern is that for each rotation salts are accumulating in the agricultural system either in soil profile or in the ground water.

Shams ul Mulk (1993) estimated that out of 33 m tons of salts coming through Indus River System annually, about 9 m tons are flown out at Kotri and remaining 24 m tons stay in the basin either in ground water or in soil profile. He further estimated that 13.6 m tons of salts remain in upper Indus basin (Punjab) and 10.4 m tons in lower Indus basin (Sindh). In Punjab 75% of this accumulation takes place in Fresh Ground Water (FGW) zone while in Sindh accumulation in sweet water zone is 25% of total addition. The author further added that drainage of salts may not be a problem in Sindh but Punjab is like a closed basin and about 11.1 m tons of salts are likely to be added to system per annum despite drainage efforts. So it is obvious that Punjab is most vulnerable from increased salt input and to attain suitable salt balance to sustain irrigated agriculture in this area ways and means to transport saline effluent need to be developed.

CONCLUSION

- Both potassic fertilizers i.e. SOP and MOP add solutes in the soil. However, salt addition through K fertilizers is small and is of little practical importance.
- Huge amount of salts comes with irrigation water which either contaminate the FGW or accumulate in the soil profile.
- Water equations for wheat-rice and sugarcane-wheat rotations are positive and salts are likely to reach the ground water where they move laterally at low pace depending upon natural relief and gradient. In wheat-cotton rotation sufficient water may not pass through root zone to take salts to saturated zone, thus solutes may accumulate in soil profile.
- Salt equation for country is positive and Punjab seems to be accumulating more salts in FGW zone which may damage our natural resources in the long run.
- Careful studies are needed to assess solute movement in soil profile for different rotations and to monitor impact of continuous salt addition through irrigation water

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