CHAPTER 6

INTEGRATED COMPARATIVE DISCUSSION ON THE EFFECTS OF WINERY EFFLUENTS ON SOIL AND POSSIBLE POLLUTION OF WATER BODIES

6.1 GENERAL

It is clear from Chapter 5 that the composition of winery effluents differ from one winery to another and also between different times during the wine making season at any specific winery. The pollution associated with winery effluents will, therefore, also differ from one winery to the other and between different months at any specific winery. The quality of winery effluent will determine the extent of pollution it will cause to the soil it has been disposed on, as well as off-site pollution that it may cause.

The properties, characteristics and qualities of the soil at the disposal site will also affect the on-site impact of the pollution, while these together with the position of the disposal site in the landscape will affect the off-site pollution hazard. These aspects are discussed in more detail in Chapters 4 and 7.

6.2 PHOSPHORUS TRENDS

From Tables 6.1, 6.2 and 6.3 it is clear that phosphorus shows some disconcerting trends at most of the wineries. The topsoils of the vast majority of the wineries show excessive to highly excessive P levels during December and January, before the start of the wine making season (Table 6.1). Taking into account that P level of 45 $mg.kg^{-1}$ is the maximum permissible level for optimum plant growth (for P extracted with the Bray 1 method) such levels are unacceptable.

Thereafter the topsoil P values decrease sharply, to even reach acceptable levels for half of the wineries, until March. In April, just after the wine making season, there is a significant increase in topsoil P to unacceptably high levels at all wineries except the two Robertson wineries.

At the Stellenbosch and Orange River wineries the topsoil P levels during April were extremely high and totally unacceptable – even higher than in December and January. At the Stellenbosch winery this high topsoil P level persisted even during May.

Phosphorus levels are generally higher in the topsoils (0 – 30 cm depth) than in the subsoils (30 – 60 cm and 60 – 90 cm) (Tables 6.1, 6.2 and 6.3). This is a general pattern for P applied to topsoils, since P normally does not move in soils, even in sandy soils under excessive irrigation (Eloff, 1971). In the present study there were some wineries where subsoils contained high to excessive P levels at some stages, indicating P movement in the soil and definite dangers of P leaching from the soil to water bodies, which could cause eutrophication of such water bodies. Most alarming in this regard are the extremely high P levels in the lower subsoil (60 – 90 cm) at the Worcester and Robertson 1 wineries during April (Table 6.3).

The phosphorus levels found in the soil at the Olifants River winery are extremely high, as is the case with most other elements at this winery. It could be argued that this shows that ponding on this dense soil efficiently retained this potential pollutant within the pond.

Unfortunately no P analyses were done on the effluents. Since disposal of effluent is done by means of ponding in the case of two of the wineries with very high P levels in the soil, the effluent is the only possible source of the high P levels. P can get into the effluent by means of washing soaps. It is clear that phosphorus management will have to be improved drastically at almost all the wineries, and especially at the Stellenbosch and Robertson 1 wineries. At these wineries there are not only clear indications of P leaching, but their disposal sites are also close to streams.

Table 6.1 Phosphorus (mg/kg) in topsoil (0 – 30 cm)

Months	Paa 1	Paa 2	Paa 3	Stell	Worc	Rob 2	Rob 1	Berg	Olif	Oran
Dec	104	53	33	185	164	-	116	137	692	103
Jan	131	93	25	143	121	-	39	130	227	136
Feb	46	14	2	69	57	38	27	22	457	64
Marc	55	24	41	84	39	25	16	27	313	83
Apri	73	49	61	275	54	31	36	85	549	230
May	76	9	-	259	35	-	33	16	133	70
Control	62	5	94	50	40	-	33	1	23	45

Table 6.2 Phosphorus (mg/kg) in upper subsoil (30 – 60 cm)

Months	Paa 1	Paa 2	Paa 3	Stell	Worc	Rob 2	Rob 1	Berg	Olif	Oran
Dec	50	54	14	119	142	-	46	-	872	84
Jan	122	31	6	63	125	-	25	62	395	70
Feb	22	12	2	53	30	-	120	47	3173	64
Marc	28	3	3	18	72	-	16	3	138	62
Apri	33	23	13	41	101	-	56	8	858	90
May	5	1	-	97	44	-	21	32	626	55
Control	26	2	74	27	11	-	23	0	33	31

Table 6.3 Phosphorus (mg/kg) in lower subsoil P (60 – 90 cm)

Months	Paa 1	Paa 2	Paa 3	Stelle	Worc	Rob 2	Rob 1	Berg	Olif	Oran
Dec	23	6	24	25	60	-	81	-	572	145
Jan	66	-	4	53	68	-	17	-	-	49
Feb	8	37	93	96	4	-	81	-	-	42
Marc	6	3	2	62	76	-	44	2	126	45
Apri	9	19	16	22	191	-	170	-	-	81
May	5	1	-	24	19	-	24	-	124	61
Control	7	2	25	14	6	-	23	4	-	10

6.3 POTASIUM TRENDS

Like phosphorus, potassium levels in the soils at most wineries were high to very high in December and January (Tables 6.4, 6.5 and 6.6). Unlike P these elevated K levels were not confined to the topsoil, but occurred at all soil depths.

Except for the very high December and January K levels at the Berg River winery, none of the values are expected to negatively affect plant growth. The very high K levels in the soil at the Berg River winery is in line with the high K levels in the effluents from this winery, as indicated in Chapter 4. (See also Table 5.7.)

Similar to P the K levels dropped sharply in February and March, in many cases to abnormally low values. Some of the February and March values are so low that they represent deficient K levels for plants. The reasons for these exceptionally low levels during these (the wine making months) are not clear.

During April the topsoil K levels rise sharply again, similar to P. In some cases elevated K levels persisted into May. The high soil K levels in April and May are attributed to the high K contents of the effluents of most cellars in March or April (Table 5.7).

Like with all other elements, the Olifants River winery also showed abnormally high values of potassium, both in the topsoil and in the subsoil. Like with P it could possibly be argued that this indicates efficient ponding, but the fact is that the effluent from this winery had abnormally high K levels in almost all months (Table 5.7).

The indication that at some wineries potassium is leaching from topsoil to subsoil and then probably to groundwater or streams is, a matter for concern. The situation at the Stellenbosch and Robertson 1 wineries, where disposal is done on highly permeable soils with low nutrient retention capacities close to streams, should receive urgent attention in this regard. There should also be much concern about the increase in K levels with depth to a very high level in the lower subsoil (60 – 90 cm) at Paarl 2 in the May samples. K toxicities are not expected, but eutrophication, which could lead to algal growth.

Table 6.4 Potassium (mg/kg) in topsoils (0 – 30 cm)

Months	Paa 1	Paa 2	Paa 3	Stell	Worc	Rob 2	Rob 1	Berg	Olif	Oran
Dec	199	156	325	387	59	-	414	1028	6100	23
Jan	289	207	168	524	63	-	469	1685	3648	266
Feb	27	23	16	39	12	70	20	129	716	47
Marc	47	20	39	63	4	82	35	117	485	27
Apri	223	94	184	551	47	555	66	598	9548	289
May	196	74	-	242	70	-	16	301	297	184
Control	145	129	199	78	47	-	235	160	821	364

Table 6.5 Potassium (mg/kg) in upper subsoils (30 – 60 cm)

Months	Paa 1	Paa 2	Paa 3	Stell	Worc	Rob 2	Rob 1	Berg	Olif	Oran
Dec	106	481	180	207	55	-	168	-	6983	23
Jan	106	82	164	301	51	-	364	981	4145	242
Feb	8	12	31	27	20	-	8	109	454	66
Marc	20	12	23	47	0	-	20	176	297	23
Apri	215	55	59	239	31	-	0	520	5353	192
May	235	590	-	109	27	-	70	348	1310	192
Control	66	90	109	74	27	-	242	102	751	266

Table 6.6 Potassium (mg/kg) in lower subsoils K (60 – 90 cm)

Months	Paa 1	Paa 2	Paa 3	Stell	Worc	Rob 2	Rob 1	Berg	Olif	Oran
Dec	47	555	20	422	31	-	145	-	2057	35
Jan	70	-	35	348	27	-	184	-	-	192
Feb	4	16	4	27	16	-	16	-	-	63
Marc	8	8	0	59	12	-	20	94	282	16
Apri	211	55	465	141	31	-	86	-	-	203
May	235	895	-	66	8	-	55	-	649	227
Control	35	258	51	125	35	-	145	59	-	141

6.4 ESP TRENDS

It is clear from Tables 6.7, 6.8 and 6.9 that almost all wineries have unacceptably high ESP levels in the topsoil and/ or subsoil of their effluent disposal sites in some of the months.

At most wineries seasonal trends similar to those for P and K are also found for ESP, viz. highest values in December, January and April. Three wineries (Paarl 2, Paarl 3 and Robertson 1) have remarkably high ESP values in the subsoils of their disposal sites.

In contrast the ESP values of the soil at the Berg River winery are low throughout, whereas a few other wineries also generally do not look too bad. It is a matter of fact that there is sodium pollution at most of the wineries. This could in most cases be clearly related to high sodium levels and SAR values of the effluent. The main sources of sodium in the effluent during wine making include technologies that employ and utilize sodium hydroxides diluted to 5% (better known as caustic soda) (Van Schoor, 2000). At the winery with the worst sodium problem (Paarl 2), the use of sodic borehole water was the main source of sodium.

At Paarl 3 the subsoil has very high sodium levels despite no indication of high sodium in the effluent. The manager of the winery was very cooperative, but could not find any explanation for this situation. (See also Chapter 4.)

According to the literature, high ESP causes the clay to become dispersed and puddle when wet, lowering infiltration, permeability and aeration and forming a hard impermeable crust when dry. In the present study indications of such effect was found at only one winery, probably because effluent disposal was in most cases done on sandy soils. High ESP may also contribute to dispersion of the organic fraction in the effluent and its leaching into the deeper subsoils. (See Chapter 7.)

Table 6.7 ESP of topsoils (0 – 30 cm)

Months	Paa 1	Paa 2	Paa 3	Stelle	Worc	Rob 2	Rob 1	Berg	Olif	Oran
Dec	8.52	25.47	3.03	10.37	13.10	-	24.60	5.52	18.41	7.55
Jan	3.46	17.31	1.48	5.23	1.49	-	25.15	2.39	20.47	2.86
Feb	3.73	19.30	11.76	5.50	12.0	6.57	6.42	5.63	5.40	11.43
Marc	6.38	16.67	3.03	7.14	0.97	5.78	2.03	2.13	4.10	3.23
Apri	5.38	14.17	2.56	8.22	1.21	6.05	4.09	3.44	29.19	5.45
May	7.9	19.89	-	12.80	2.06	-	10.10	2.83	14.08	5.41
Control	2.53	4.19	1.90	0.78	1.81	-	2.28	7.51	17.40	2.12

Table 6.8 ESP of upper subsoils (30 – 60 cm)

Months	Paa 1	Paa 2	Paa 3	Stelle	Worc	Rob 2	Rob 1	Berg	Olif	Oran
Dec	7.05	17.24	50.35	17.45	19.50	-	30.46	-	18.24	10.99
Jan	4.68	12.50	29.22	6.22	1.54	-	25.22	1.93	14.23	4.14
Feb	3.17	22.86	22.64	12.50	6.86	-	21.21	7.00	7.61	8.51
Marc	3.26	21.05	20.45	11.43	0.00	-	9.09	1.82	1.75	4.26
Apri	6.29	22.22	22.18	9.06	1.06	-	6.04	3.80	24.41	5.37
May	7.54	16.83	-	10.42	1.75	-	10.49	3.31	4.71	1.82
Control	2.22	6.47	2.07	0.95	1.38	-	1.73	3.16	40.31	3.0

Table 6.9 ESP of lower subsoils (60 – 90 cm)

Months	Paa 1	Paa 2	Paa 3	Stelle	Worc	Rob 2	Rob 1	Berg	Olif	Oran
Dec	7.29	17.67	66.84	16.93	29.79	-	7.80	-	9.27	13.44
Jan	5.50	-	38.45	7.56	1.78	-	22.41	-	-	3.99
Feb	4.17	21.74	23.63	15.25	8.75	-	12.07	-	-	5.76
Marc	2.30	19.05	18.60	7.69	0.00	-	8.70	6.25	2.04	4.88
Apri	4.90	23.67	39.28	12.61	1.07	-	1.73	-	-	5.25
May	9.24	15.47	-	10.22	1.39	-	14.07	-	2.35	1.82
Control	4.96	6.11	2.34	1.49	1.56	-	1.9	2.34	-	3.43

6.5 MANGANESE, ZINC AND COPPER

Orange river, Olifants river and Berg river wineries have high manganese values even in the subsoil. At these three wineries there are indications that there is leaching from topsoil to subsoil and may therefore even leach to groundwater or streams. Manganese pollution can be expected at these three wineries. Other wineries (Paarl 1, Paarl 3 and Robertson 2) have some indication of high manganese values in the topsoil in one or two months. There is no clear trend shown by manganese as it differs from one winery to the other. The sources of these elements are at this stage unknown because it can not be related to winery processes. Spray drift from vineyards in close proximity during spray could be speculated as possible source but was not measured in this study.

Like manganese, zinc is very high at all depths in the soil at three wineries (Orange river, Olifant river and Berg river). Two other wineries (Stellenbosch and Paarl 3) have high zinc values in the topsoil during certain months.

Most wineries do not have high levels of copper in their soils. Only two wineries (Orange river and Berg river) have high values of copper in most of the months in both the topsoil and subsoil. This is an indication that it may leach to the groundwater or streams, therefore polluting the environment.

6.6 RESPONSE OF MINERAL ELEMENT LEVELS IN SOILS TO ITS LEVELS IN EFFLUENT

As indicated earlier, there is evidence that mineral element levels in soils rise and fall in response to fluctuations in the levels of these elements in the effluent. There is usually a lag in this response, i.e. the increase in the level in the soils is usually in the month following the month in which an elevated level occurred in the effluent. The same holds for sharp decreases in mineral element levels. Sometimes there is a further lag with depth, especially for P, but in the case of the sandy soils the changes occur simultaneously at all depths, due to fast leaching.

These effects are clearly illustrated for K and Na at the Orange River winery (Figures 6.1 and 6.2). For both elements there are sharp increases in their levels in the soil at all depths in April, following their sharply increased levels in the March effluent. Conversely their levels in the soil decreased sharply in February, following their high levels in the soil in January, in response to their low levels in the January effluent. Unfortunately no analyses are available for the December effluent, so that it can only be speculated that the high levels of these elements in the soil in January were due to high levels in the December effluent.

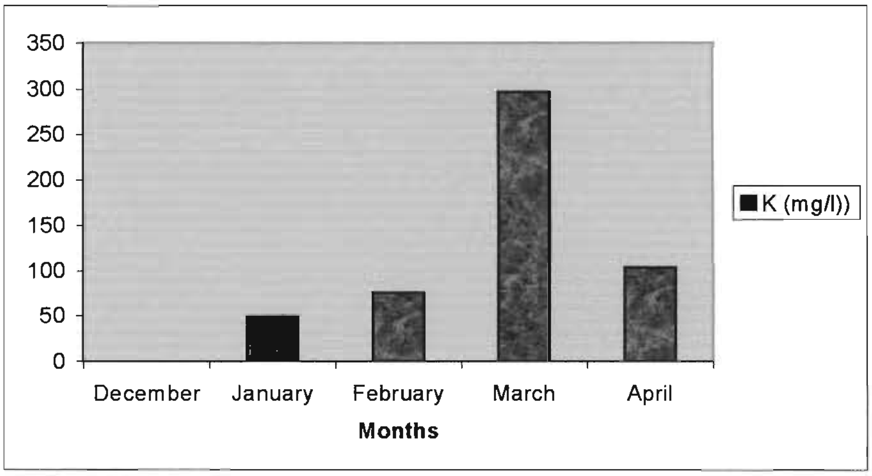

Figure 6.1a: Potassium trend of effluent at Orange river winery

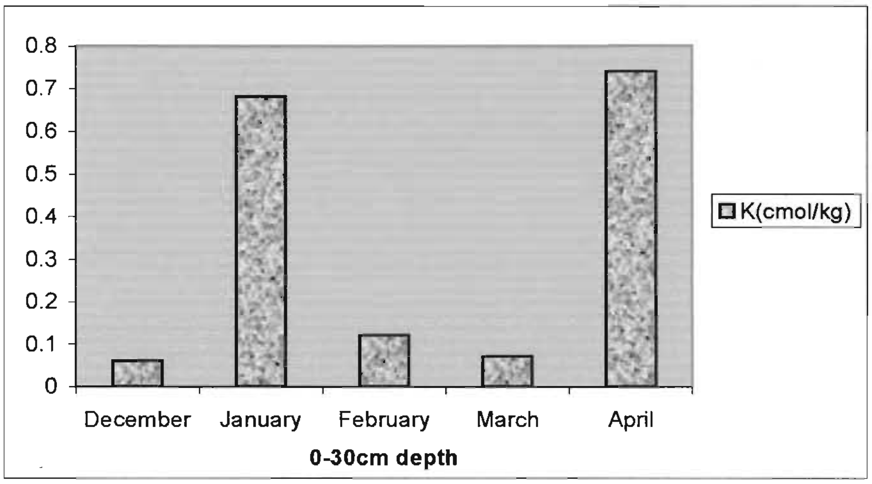

Figure 6.1b: Potassium trend of topsoil (0-30 cm) at Orange river winery

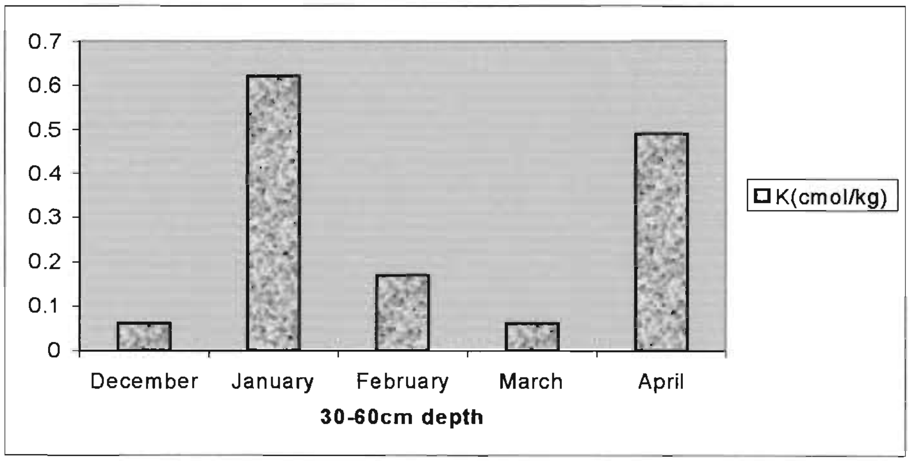

Figure 6.1c: Potassium trend of subsoil (30-60cm) at Orange river winery

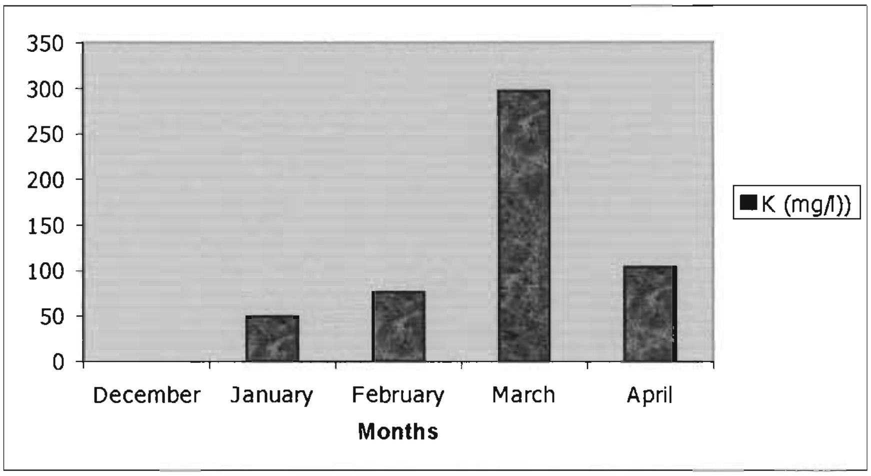

Figure 6.1a: Potassium trend of effluent at Orange river winery

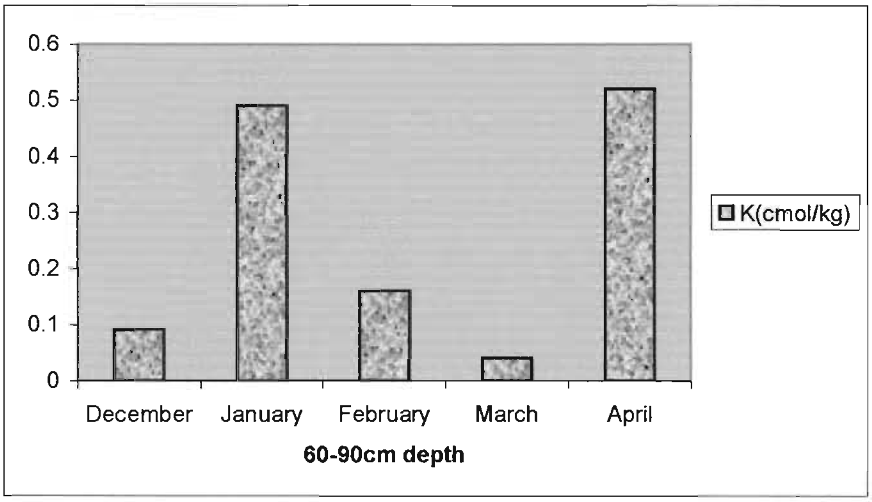

Figure 6.1d: Potassium trend of subsoil (60-90cm) at Orange river winery

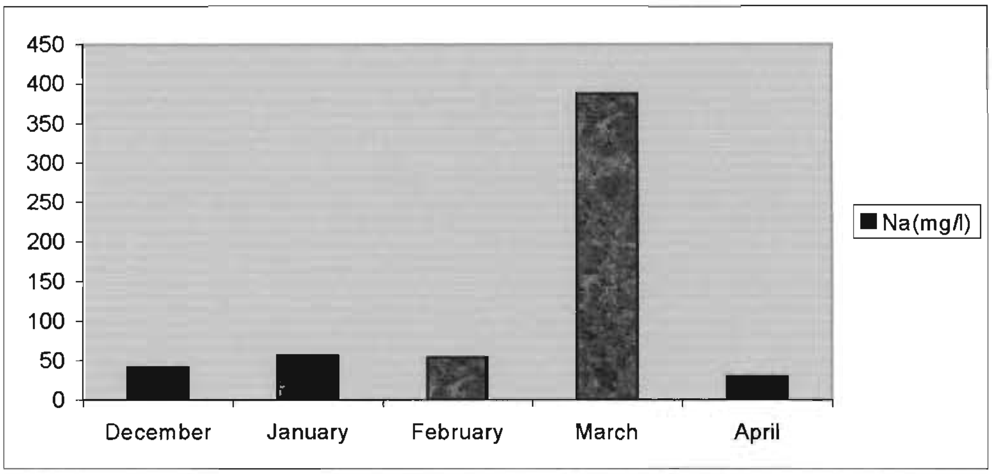

Figure 6.2a: Sodium trend of effluent at Orange river winery

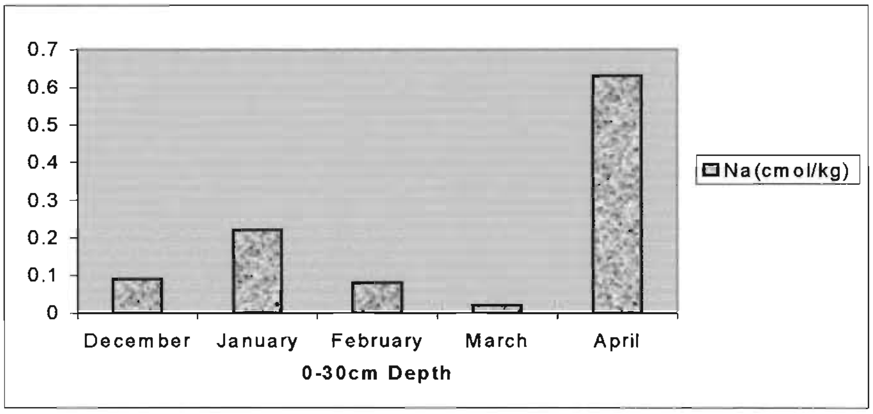

Figure 6.2b: Sodium trend of topsoil (0-30cm) at Orange river winery

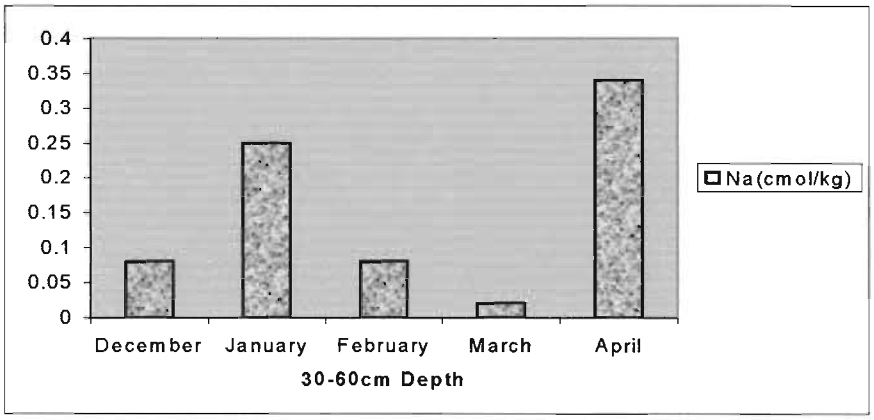

Figure 6.2c: Sodium trend of subsoil (30-60cm) at Orange river winery

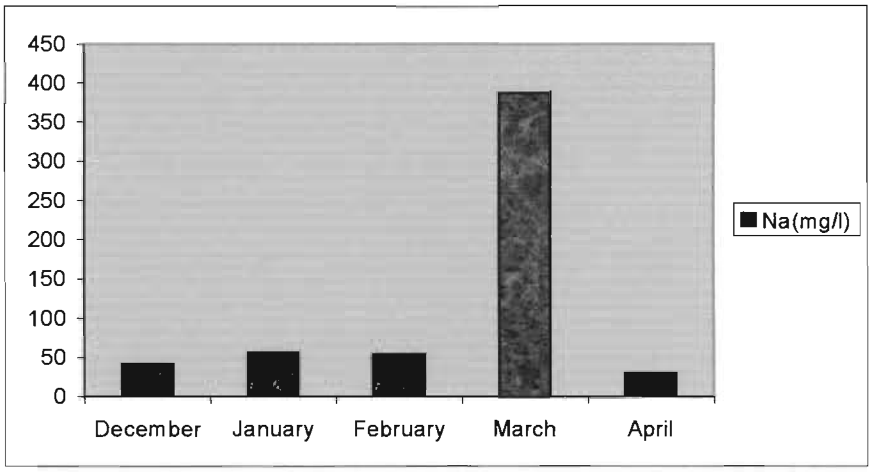

Figure 6.2a: Sodium trend of effluent at Orange river winery

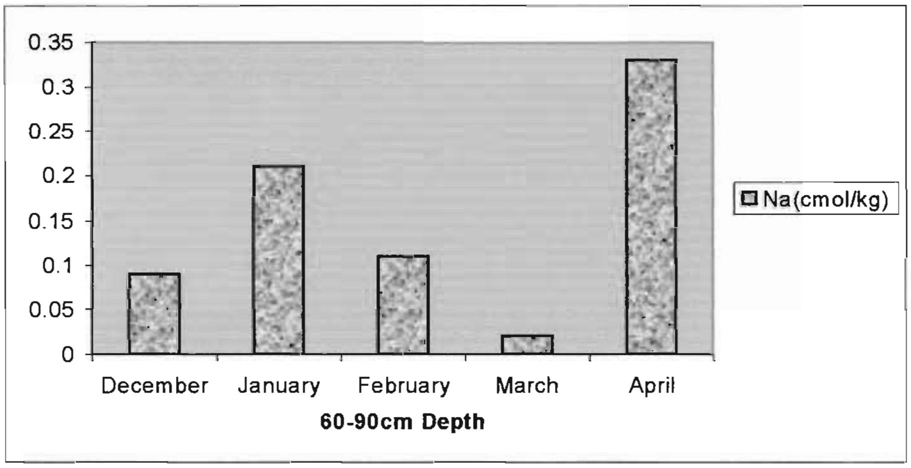

Figure 6.2d: Sodium trend of subsoil (60-90cm) at Orange river winery