



# Understanding Different Soil Test Methods

## Nutrient Management Factsheet – No. 3 in Series

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Soil test results from different laboratories can be quite different for what seems to be the same soil sample, like when a sample is split to be analyzed by more than one lab. One explanation is that the labs actually received different samples. This can happen if the original soil sample is not mixed thoroughly before it is split and if the subsamples are not preserved well before they reach the lab(s). See the *Sample handling* section of Factsheet 2, *Soil Sampling for Nutrient Management*, for more information. Nonetheless, two labs that are ‘doing everything right’ can provide different values for the same nutrient of interest because of differences in the soil test methods between the labs.

This factsheet provides information to compare soil test results of different methods. Simple conversion factors are provided to help compare results of common phosphorus (P) and potassium (K) methods or ‘extractants’ to be more specific. These conversions are built into the Nutrient Management Planning (NMP) software produced for the Canada-BC Environmental Farm Plan program.

Because various factors of test methods can influence results, this factsheet first outlines some of the key factors behind conventional soil test P and K methods and notes for understanding the simple conversion factors.

### Key Factors of Soil Test Methods

A conventional soil nutrient test method has the following factors:

- **the extractant**
- weighing versus scooping (by volume) soil
- soil to extractant ratio
- soil extraction time
- extraction temperature
- **the quantification method**

#### The extractant

An extractant is a chemical solution that is added to a soil sample to ‘dissolve, desorb or exchange’ a portion of the total amount of a given nutrient(s) in the soil sample. This portion should provide a crude but useful index of the portion of a nutrient in soil that will be available to a crop through soil processes. In contrast, a measure of the total amount of an element is in a sense, a more crude measurement because it is not meant to distinguish between portions of a nutrient, some of which are plant-available and some of which are not.

Some extractants were developed for a single nutrient or element; others for multiple nutrients or elements. For any particular nutrient (e.g. phosphorus), different extractants may remove different portions of the nutrient, because each extractant was originally developed for a different soil type or purpose.

The extractant is the main factor considered in the NMP software and in the conversion factors between common extractants provided below (**Tables 1 and 2**).

## The quantification method

A quantification method determines the amount of a nutrient(s) in the extraction solution after the nutrient(s) has been extracted from a soil.

Some quantification methods are non-selective and measure the total amount of a nutrient element(s), *i.e.* *inorganic* + *organic*

- e.g. Inductively Coupled Plasma (ICP)

Others are selective and measure a fraction of the total amount of a nutrient in a specific molecular form, *i.e.* *inorganic*

- e.g. colorimetry
- e.g. ion chromatography

## Relationships between Extractants for Soil Phosphorus and Potassium

A recent study compared results of common soil test extractants for soil P and K. Highlights are presented below. Please refer to the full report<sup>3</sup> for more information.

### Methods

The extractants in **Table 1** were used to determine soil test P and K contents of a total of 990 soil samples collected during the Fraser Valley (2005)<sup>4</sup> and Okanagan-Similkameen (2007)<sup>5</sup> soil studies representing a broad range of soil types and nutrient levels in the two regions. Soil to extractant ratio (1:10 w/w) and soil extraction time (5 minutes) were standardized for all extractants except bicarbonate (1:20 w/w and 30 minutes instead), and quantification was by ICP for all extractants.

In British Columbia, the Kelowna extraction method was the last provincial standard publicly developed for soil phosphorus and potassium testing for agronomic purposes<sup>6</sup>. Thus, the relationships in Tables 1 and 2 are comparisons between the Kelowna extractant and other extractants.

Some colorimetric methods have unavoidable interference problems that can result in under- or over-estimates of the true values, and the error varies between soils<sup>1,2</sup>. This interference means that measurements are only 'sometimes right.' This affects P (and sulphur) measurements in particular. It should not affect soil K measurements (since organic K compounds do not occur).

To use the NMP software, soil test results should be treated as roughly equivalent at this time for all quantification methods unless otherwise indicated. In other words, there is no need to know the laboratory's specific quantification method: just be aware that it is one other factor of the soil test besides the extractant that can explain differences in soil test (phosphorus) results.

### Results

Disclaimers:

- The relationships in **Table 1** may not apply exactly to commercial laboratories' results because the relationships are effectively a comparison of *extractants'* abilities to extract P. They are not a comparison of specific laboratories' methods, which are difficult to compare since they vary in the factors of a soil test method (soil-to-extractant ratios, extraction times, and quantification methods) for the same extractant.
- The relationships in **Table 2** are expected to produce reliable estimates for soil test potassium.
- The relationships indicate how well the Kelowna extractant compares with other extractants. However, the study was limited in the sense that it was not designed to indicate how well different extractants reflect the response of crops to additional fertilizer.

*Example calculation:*

A result of 86 ppm P (Bray-1 method) in a soil of pH 5.3 is approximately equivalent to 64 ppm P (Kelowna method) according to Table 1, which is approximately equivalent to 51 ppm P (Modified Kelowna-95 method)<sup>7</sup>.

**Table 1.** Relationships between soil test P extractants and the Kelowna extractant for British Columbia soils.

Kelowna-P = <b>0.74</b> * Bray-1 P	pH < 7.2	r <sup>2</sup> = 0.96
Kelowna-P = <b>1.00</b> * Bray-1 P	pH ≥ 7.2	r <sup>2</sup> = 0.85
Kelowna-P = <b>0.99</b> * Bicarbonate (Olsen) P	pH < 7.2	r <sup>2</sup> = 0.99
Kelowna-P = <b>1.21</b> * Bicarbonate (Olsen) P	pH ≥ 7.2	r <sup>2</sup> = 0.96
Kelowna-P = <b>0.72</b> * Mehlich-3 P	all pH values	r <sup>2</sup> = 0.98
Kelowna-P = <b>1.24</b> * Modified Kelowna-95 P <sup>7</sup>	all pH values	r <sup>2</sup> = 0.96

<sup>7</sup> Ashworth and Mrazek 1995.

At the time of writing, the Exova laboratory in Edmonton, AB (formerly Bodycote) used this soil test P extractant.

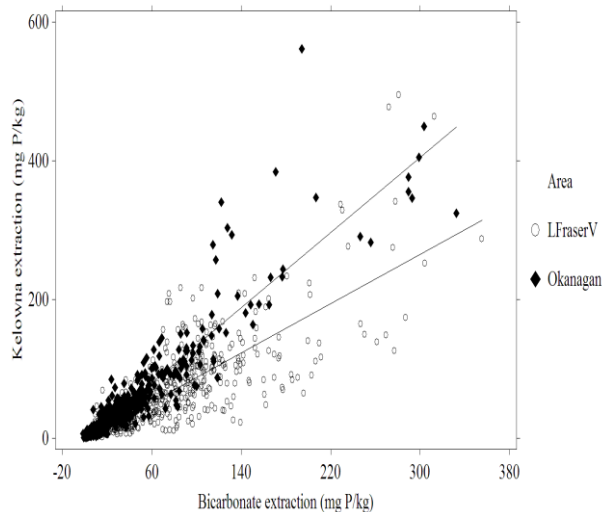
An alternative relationship between Kelowna-P and bicarbonate-P is recommended to be used by the default (i.e. unless the laboratory is known to use ICP for the bicarbonate-phosphorus measurements, use the following):

$$\text{Kelowna P} = 2 * \text{Bicarbonate (Olsen) P-colorimetry}$$

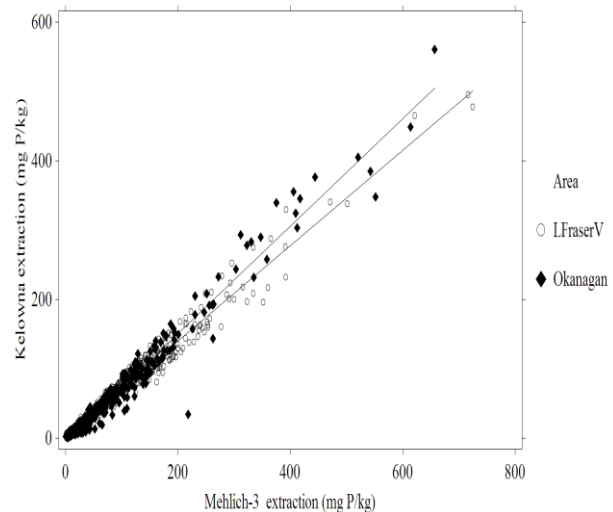
Rationale: Most commercial laboratories use colorimetry instead of ICP to quantify phosphorus for bicarbonate extractions, which in turn is a common extraction for calcareous soils. The alternative relationship does not come from the study that produced results in Table 1. It is based loosely on results of previous studies<sup>8,9</sup> that cannot be directly compared because of differences in methods, particularly the use of interference-prone colorimetry. The colorimetry distinction is made only for bicarbonate because compared to the other extractants in Table 1, it is in its own ‘family’ of chemical solutions and has been found to extract more organic P<sup>3</sup>.

### What do the r<sup>2</sup> values mean?

Greater r<sup>2</sup> values indicate a ‘stronger’ relationship. Values can range from 0 (no relationship) to 1 (perfect relationship). The bicarbonate-Kelowna P relationship (Figure 1) is ‘weaker’ than the Mehlich 3-Kelowna P relationship (Figure 2) for most soils, as shown by a greater spread of data points around the line for the ‘bicarbonate’ graph compared to the ‘Mehlich 3’ graph.



**Figure 1.** Bicarbonate P vs. Kelowna P for soil samples from the Lower Fraser Valley and Okanagan-Similkameen of BC.



**Figure 2.** Mehlich3-P vs. Kelowna P for soil samples from the Lower Fraser Valley and Okanagan-Similkameen of BC.

**Table 2.** Relationships between soil test K extractants and the Kelowna extractant for British Columbia soils.

Kelowna-K = <b>0.80</b> * Ammonium Acetate K	all pH values	$r^2 = 0.98$
Kelowna-K = <b>0.75</b> * Mehlich-3 K	all pH values	$r^2 = 0.99$
Kelowna-P = <b>0.76</b> * Modified Kelowna-95 K <sup>7</sup>	all pH values	$r^2 = 0.97$

<sup>7</sup> Ashworth and Mrazek 1995.

At the time of writing, the Exova laboratory in Edmonton, AB (formerly Bodycote) used this soil test K extractant.

## Converting between ppm and kg/ha

To convert between “parts per million” (ppm) and “kilograms per hectare” (kg/ha) requires values for the soil bulk density (in kg/m<sup>3</sup>) and the depth of the soil layer sampled (in metres). The following are rules of thumb for mineral soils that assume soil bulk density is 1000 kg/m<sup>3</sup>.

### 1) Converting ppm to kg/ha

If sample depth was 0.15 m (15 cm or 6 inches),

**then** Value in kg/ha = Value in ppm x 1.5

*Rationale:* Value in kg/ha = Value in ppm x (1 kg/10<sup>6</sup> mg) x (1000 kg/m<sup>3</sup>, bulk density) x (0.15 m x 10<sup>4</sup> m<sup>2</sup>/ha)

*Example:* 50 ppm P = approx. 75 kg P/ha

### 2) Converting kg/ha to ppm

If sample depth was 0.30 m (30 cm or 1 foot),

**then** Value in ppm = Value in kg/ha ÷ 3.0

*Rationale:* Value in ppm = Value in kg/ha ÷ (1 kg/10<sup>6</sup> mg) ÷ (1000 kg/m<sup>3</sup>, bulk density) ÷ (0.30 m x 10<sup>4</sup> m<sup>2</sup>/ha)

*Example:* 200 kg N/ha = approx. 67 ppm N

You may choose to use a different value than 1000 kg/m<sup>3</sup> to convert your values. Average soil bulk densities for mineral soils are as follows:

Well structured high organic loam soil	900 kg/m <sup>3</sup>
Silt loam	1100 kg/m <sup>3</sup>
Medium to fine texture loam	1300 kg/m <sup>3</sup>
Sand	1500 kg/m <sup>3</sup>
Compacted soil or clay subsoil	1300-1600 kg/m <sup>3</sup>

For mineral soils, a soil test value on a weight basis (mg/kg or µg/g) is roughly the same as on a volume basis (mg/L or µg/mL). Because bulk densities for Organic soils vary widely (e.g. 100-700 kg/m<sup>3</sup>), this assumption should not be made for Organic soils, and thus the rules of thumb described for converting between ppm and kg/ha should not be used.

## References

1. Kowalenko, C.G. and Babuin, D. 2007. Interference problems with phosphoantimonylmolybdenum colorimetric measurement of phosphorus in soil and plant materials. *Communications in soil science and plant analysis* 38: 1299-1316.
2. Kowalenko, C.G. 2008. Extraction times and analysis methods influence soil test measurements of phosphorus and sulphur. *Canadian Journal of Soil Science* 88: 733 – 747.
3. Kowalenko, C.G. 2010. Relationships between extraction methods for soil nutrient testing in British Columbia. Report for Ministry of Agriculture and Lands.  
[http://www.agf.gov.bc.ca/resmgmt/EnviroFarmPlanning/Relationships\\_Between\\_Extraction\\_Methods.pdf](http://www.agf.gov.bc.ca/resmgmt/EnviroFarmPlanning/Relationships_Between_Extraction_Methods.pdf)
4. Kowalenko, C.G., Schmidt, O. and Hughes-Games, G.A. 2007. Fraser Valley soil nutrient study 2005. A survey of the nitrogen, phosphorus and potassium contents of the Lower Fraser Valley agricultural soils in relation to environmental and agronomic concerns. [http://www.agf.gov.bc.ca/resmgmt/EnviroFarmPlanning/FV\\_SoilNutrientStudy/FVSNS-CombinedReport\\_Feb28\\_2007\\_for\\_Release.pdf](http://www.agf.gov.bc.ca/resmgmt/EnviroFarmPlanning/FV_SoilNutrientStudy/FVSNS-CombinedReport_Feb28_2007_for_Release.pdf)
5. Kowalenko, C.G., Schmidt, O., Kenney, E., Neilsen, D. and Poon, D. 2009. Okanagan Agricultural Soil Study 2007. A survey of the chemical and physical properties of agricultural soils of the Okanagan and Similkameen Valleys in relation to agronomic and environmental concerns.  
[http://www.agf.gov.bc.ca/resmgmt/EnviroFarmPlanning/OK\\_AgricSoilStudy2007/Okanagan\\_Soil\\_Study\\_Report\\_2007.pdf](http://www.agf.gov.bc.ca/resmgmt/EnviroFarmPlanning/OK_AgricSoilStudy2007/Okanagan_Soil_Study_Report_2007.pdf)
6. Gough, N.A. 1991. (Republished in 1996.) Soil and plant tissue testing methods and interpretations of their results for British Columbia agricultural soils. Final draft report.
7. Ashworth, J. and Mrazek, K. 1995. "Modified Kelowna" test for available phosphorus and potassium in soil. *Communications in Soil Science and Plant Analysis* 26: 731-739.
8. van Lierop, W. 1988. Determination of available phosphorus in acid and calcareous soils with the Kelowna multiple-element extractant. *Soil Science* 148: 284-291.
9. Ige, D.V., Akinremi, O.O., Flaten, D., Haluschak, P. and Eilers, B. 2005. Comparison of agronomic soil test P methods for Manitoba soils. Poster presentation. <http://www.gov.mb.ca/agriculture/msss/2005/mss650.pdf>