Heavy Metal Distribution, Bioavailability and Crop response in municipal solid waste compost amended Soil

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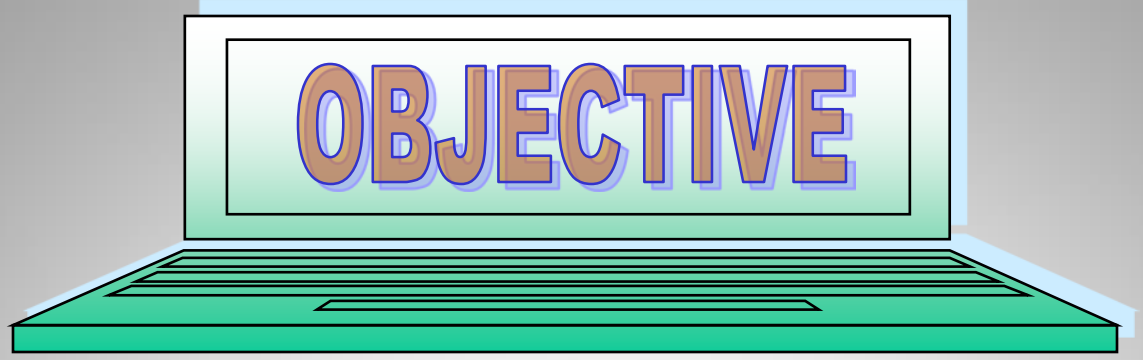
INTRODUCTION

- Soil organic matter is an important attribute of soil quality.
- Indian soils are poor in organic matter content.
- Disposal of municipal solid waste is now universal problem.
- Calcutta generates about 3400 Mg solid wastes daily.
- Composting of municipal solid waste is an attractive method of resource recovery.

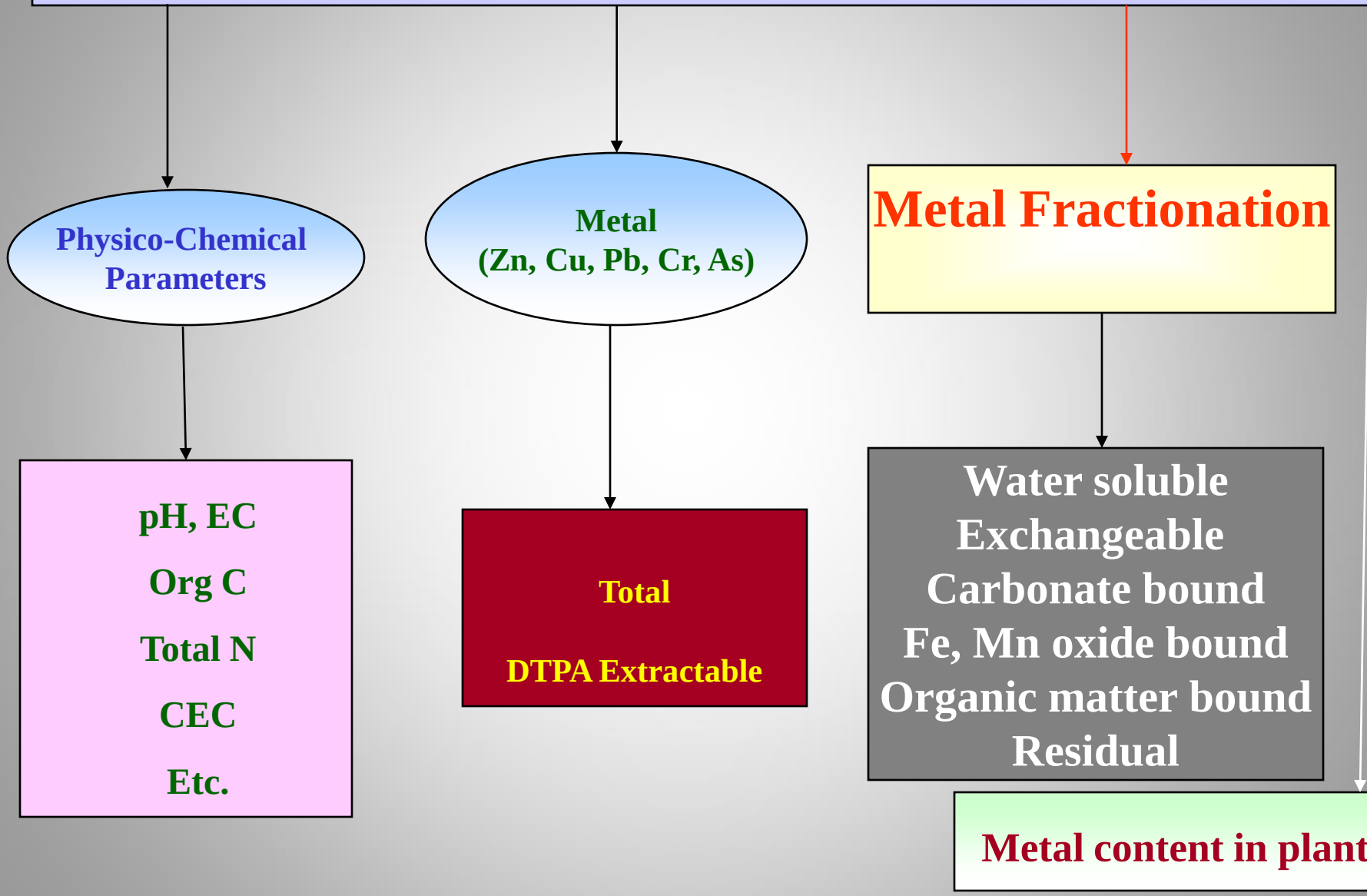
Calcutta Municipal Solid Waste



- To characterize municipal solid waste compost and cowdung manure

- To study the effects of MSWC, compared to cowdung manure alone or with chemical fertilizers on rice dry matter, straw and grain yield, nitrogen and metal uptake under field condition.

Materials and Methods



Physical and physico-chemical characteristics of municipal solid waste compost

Parameters	Range	Mean ± SE
Colour	-	Dark Brown
Odour	-	Earthy
Moisture (%)	18-25	21.90 ± 2.59
Ash content (%)	76-82	78.9 ± 0.62
Maximum W.H.C (%)	88-97	94.00 ± 0.863
Sand (%)	38-44	41.40 ± 0.514
Silt (%)	26-30	28.66 ± 2.56
Clay (%)	27-30	30.00 ± 0.435
pH	7.35-7.40	7.38 ± 0.013
EC (dS/m)	2.70-2.78	2.73 ± 0.008

Chemical characteristics of municipal solid waste compost

Parameters	Range	Mean ± SE
Organic carbon (g/kg)	101.70-118.30	107.95 ± 1.58
Total nitrogen (g/kg)	8.10-11.02	9.30 ± 0.12
C/N	10.73-12.42	11 ± 0.16
C/N-org of water extract	5.63-6.30	5.93 ± 0.55
Ammonium-nitrogen (mg/kg)	58-96	76.60 ± 3.38
Nitrate-nitrogen (mg/kg)	1180-1650	1461 ± 42.22
Total phosphorous (g/kg)	4.20-4.97	4.77 ± 0.07
Available phosphorous (mg/kg)	261-304	276 ± 5.0
Total potassium (g/kg)	15.80-18.80	16.75 ± 0.52
Available potassium (g/kg)	2.13-2.50	2.32 ± 0.03
CEC (cmol(p^+)/kg) ash free basis	71-106	93.30 ± 3.53

Humus carbon distribution in municipal solid waste compost

Parameters	Range	Mean ± SE
Organic-C (g/kg)	101.70-118.30	107.95 ± 1.579
Humus-C (g/kg)	25.00-33.00	28.2 ± 0.82
Humus-C /Organic-C (%)	24.58-28.00	26.08 ± 0.77
Humic acid-C/Organic-C (%)	16.62-19.01	17.6 ± 0.453
Humic acid-C / Fulvic acid-C	1.78-2.64	2.11 ± 0.106

Heavy metal concentration (mg/kg) of municipal solid waste compost

Metal	Parameters	Range	Mean ± SE
Zn	Total	487-599	528.40 ± 11.26
	DTPA extractable	94.27-233	145.09 ± 15.37
Cu	Total	101-190	151.6 ± 8.36
	DTPA extractable	36-74	57.4 ± 3.56
Pb	Total	214-319	269.9 ± 11.14
	DTPA extractable	87-167	131.2 ± 7.98
Cr	Total	620-678	655 ± 10.17
	DTPA extractable	55-72	66 ± 7.97
As	Total	41-66	54 ± 7.18
	DTPA extractable	4.0-5.9	4.8 ± 0.8

Comparison of metal content (mg/kg) of Calcutta MSW compost with EU and USA

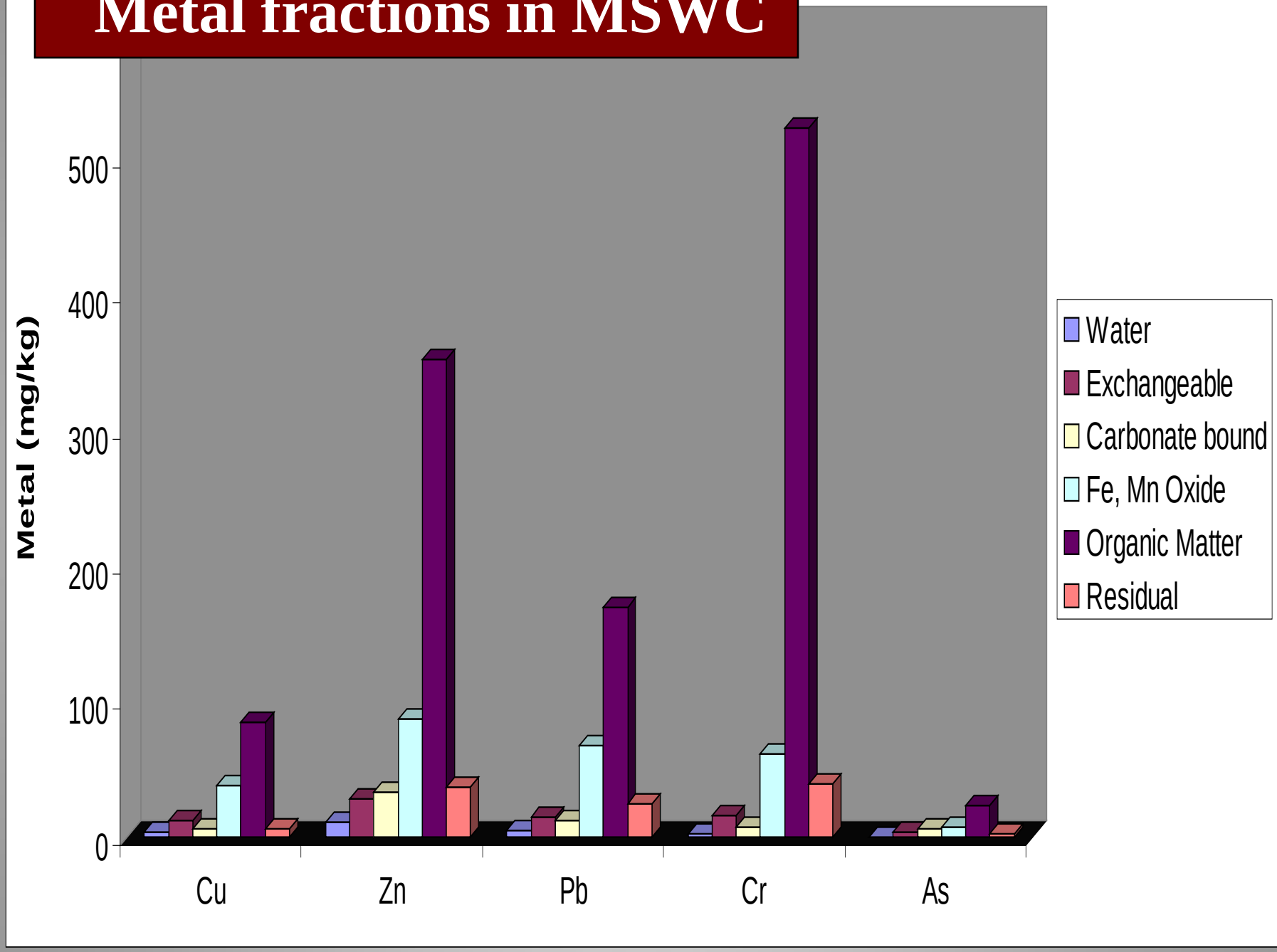
Metal	Calcutta ± SE	EU ± SE*	USA ± SE*
Zn	528 ± 11	864 ± 83	771 ± 141
Cu	152 ± 8	354 ± 53	349 ± 67
Pb	270 ± 11	565 ± 46	324 ± 55
Cr	670 ± 13	785 ± 48	718 ± 39
As	44 ± 1.7	87 ± 3.1	79 ± 2.2

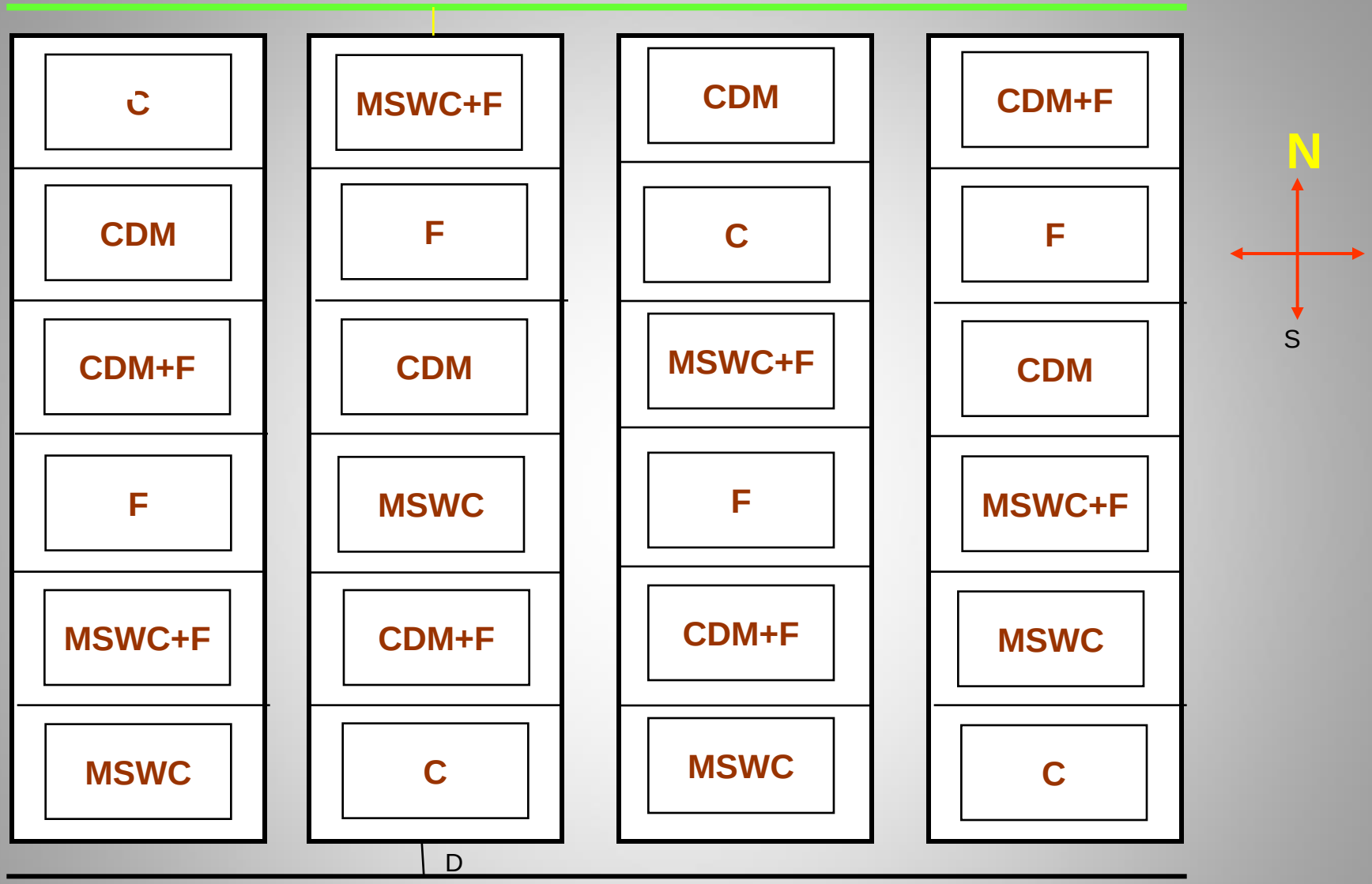
* Source: Epstein, 1997

MATURITY INDEX

Parameters	Maturity Index	Calcutta MSW compost
Colour	Dark brown	Dark brown
Odour	Smells like forest soil	Smells like forest soil
pH	7 to 8	7.38
C/N	< 20	11
C/Norg in water extract	5 to 6	5.97
NH_4^+ (%)	< 0.04	0.007
NO_3^- (mg/kg)	> 300	1461
CEC (cmol(p^+)/kg)	> 60 cmol(p^+)/kg on ash free material basis	93.3 cmol(p^+)/kg on ash free material basis
Humus-C/OC (%)	> 17.8	26.08
CO_2 Evolution	< 2 mg CO_2-C/g compost-C/day	0.28 mg CO_2-C/g compost-C/day
MBC / OC (%)	< 1.7	1.53
Pathogenic Microbe	NIL	NIL
Bacterial count	10^8-10^9	51.1x 10^8
Azotobacter count	10^3-10^5	62.8x10^5

Metal fractions in MSWC





LAY OUT OF FIELD EXPERIMENT (RANDOMISED BLOCK DESIGN)

Treatment Details

Treatment	Description
Control	No input
Municipal Solid Waste Compost (MSWC)	To supply 60 Kg N/ha.
Cow dung manure (CDM)	To supply 60 Kg N/ha
MSWC + Urea (U)	30 Kg N/ha supplied through MSWC and 30 Kg N/ha substitution by urea.
CDM + U	30 Kg N/ha supplementation by CDM and 30 Kg N/ha by urea.
Fertilizer (F)	Recommended (State Department of Agriculture, West Bengal, India) dose of 60 : 67.5 : 36 Kg N, P_2O_5 and K_2O respectively supplemented in the form of urea, single super- phosphate and muriate of potash respectively.

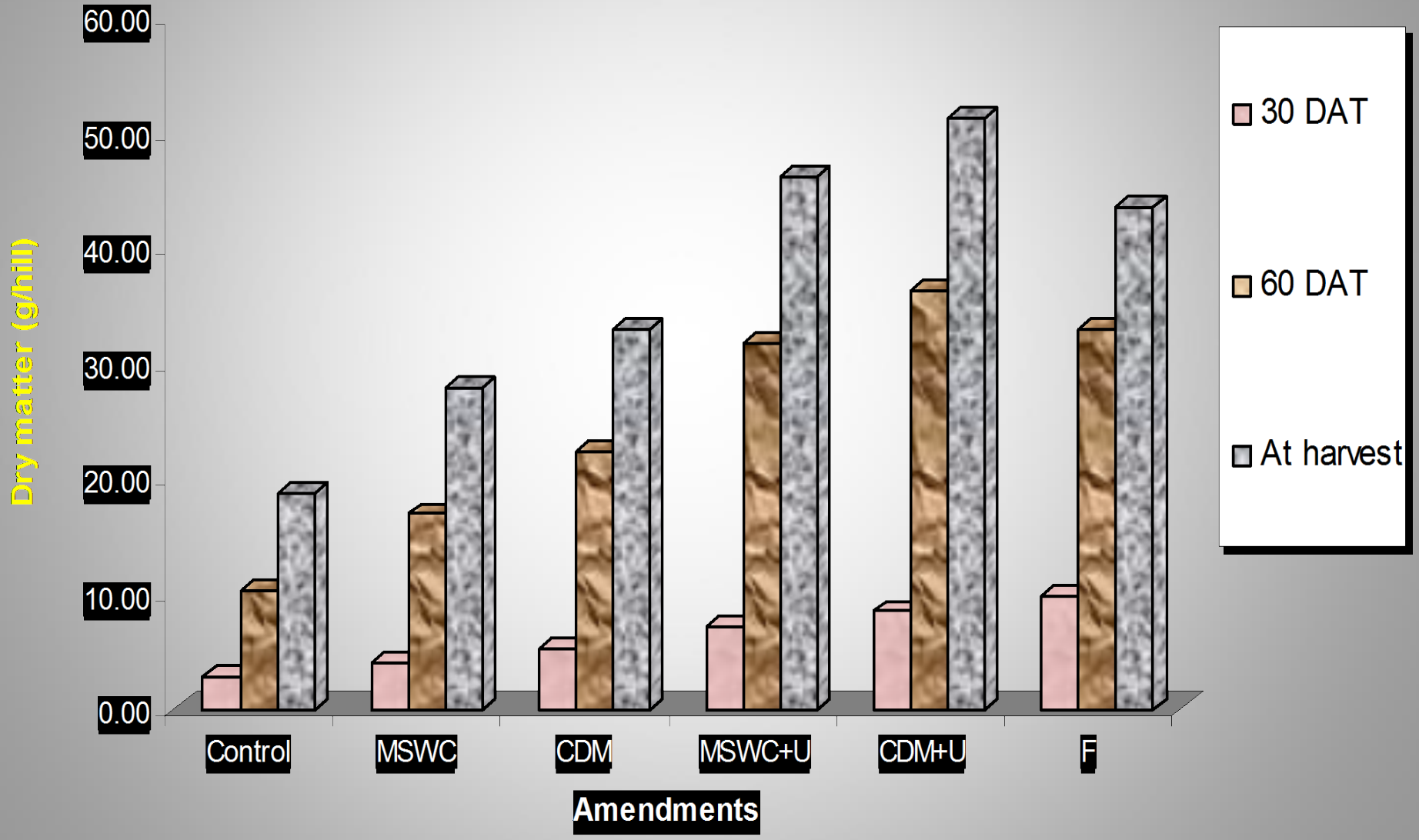
Characteristics of soil, MSWC and CDM applied to field

Parameter	Soil	MSWC			CDM		
		I	II	III	I	II	III
pH	5.5	7.40	7.40	7.40	6.11	6.20	6.22
EC (dS/m)	0.29	2.70	2.76	2.70	2.17	2.20	2.20
Organic carbon (g/kg)	13.9	114.3	111.4	113.6	110	126	127.5
Total nitrogen (g/kg)	1.70	10.10	9.88	10.01	11.80	11.40	11.60
C/N	8.20	11.31	11.27	11.34	9.32	11.05	10.99
Total S (g/kg)	0.1	6.7	7.3	7.2	1.4	1.6	1.3
CEC (cmol (p^+)/kg)	19	105	105	100	68.4	66.7	72.8

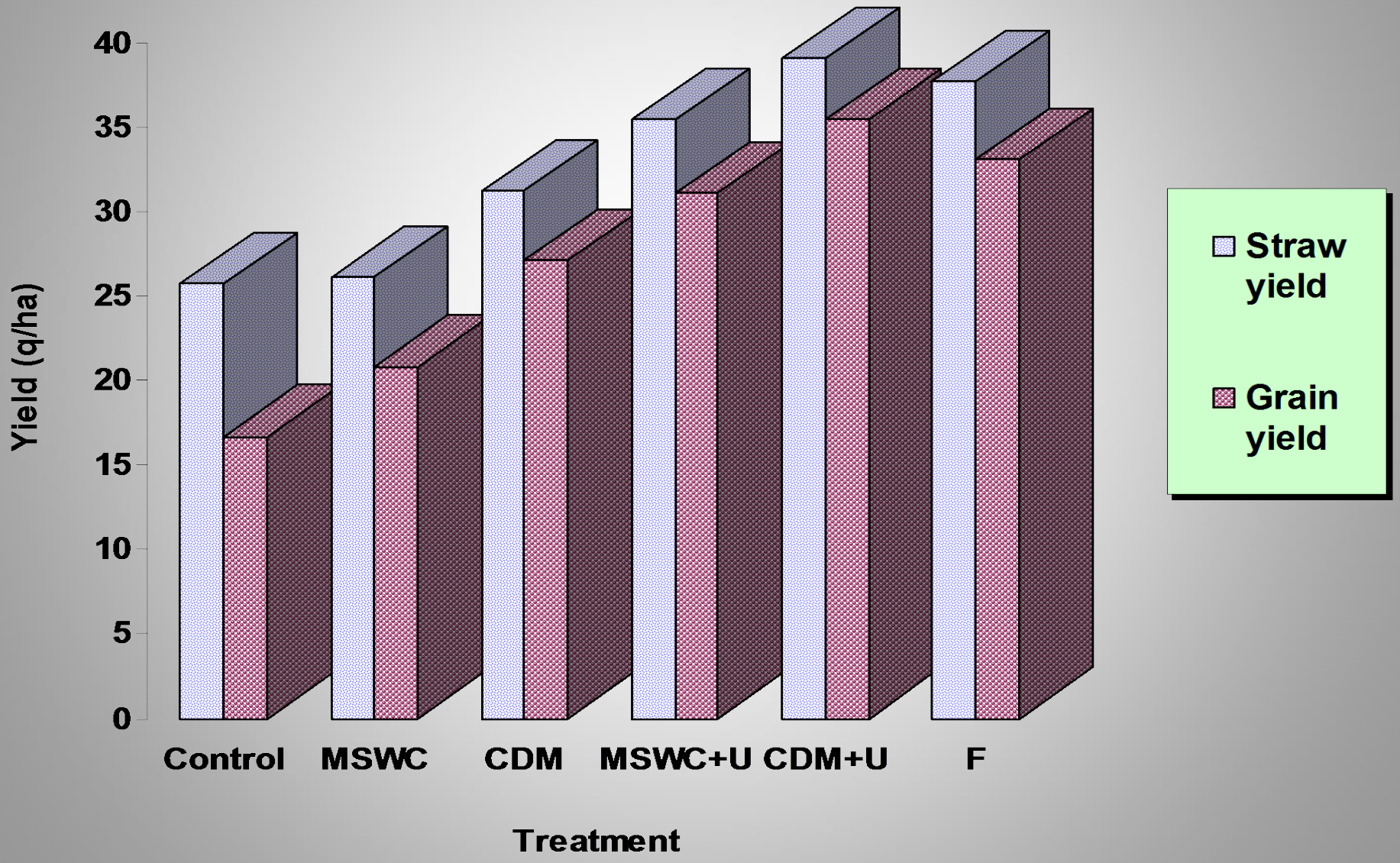
Heavy metal content (mg/kg) of soil, MSWC and CDM applied to field

Metal	Parameter	Soil	MSWC			CDM		
			I	II	III	I	II	III
Zn	Total	50	691	550	520	170	165	155
	DTPA extractable	16	213	170	200	4	3.2	3.1
Cu	Total	21	149	190	134	10	8	7
	DTPA extractable	4	74	62	63	0.25	0.18	0.17
Pb	Total	22	319	292	302	29	25	30
	DTPA extractable	3	157	152	141	0.12	0.10	0.09
Cr	Total	48	653	662	678	52.5	51.8	54.5
	DTPA extractable	8	55	58	71	14	18	20
As	Total	19	47	43	45	14	13	13
	DTPA extractable	0.36	4.1	4.1	4.3	3.7	3.5	3.5

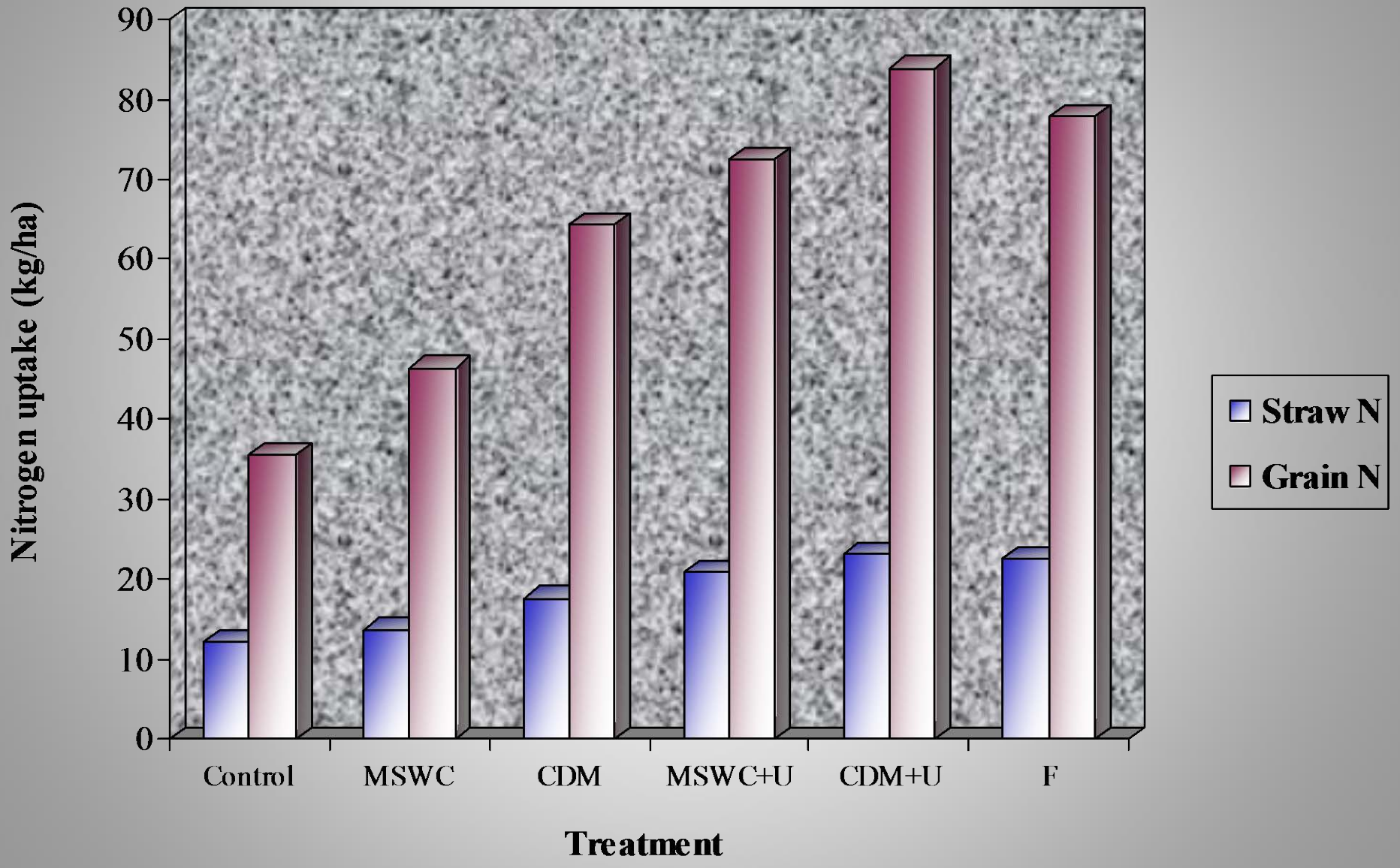
Periodic dry matter accumulation (g/hill) of rice as affected by treatments



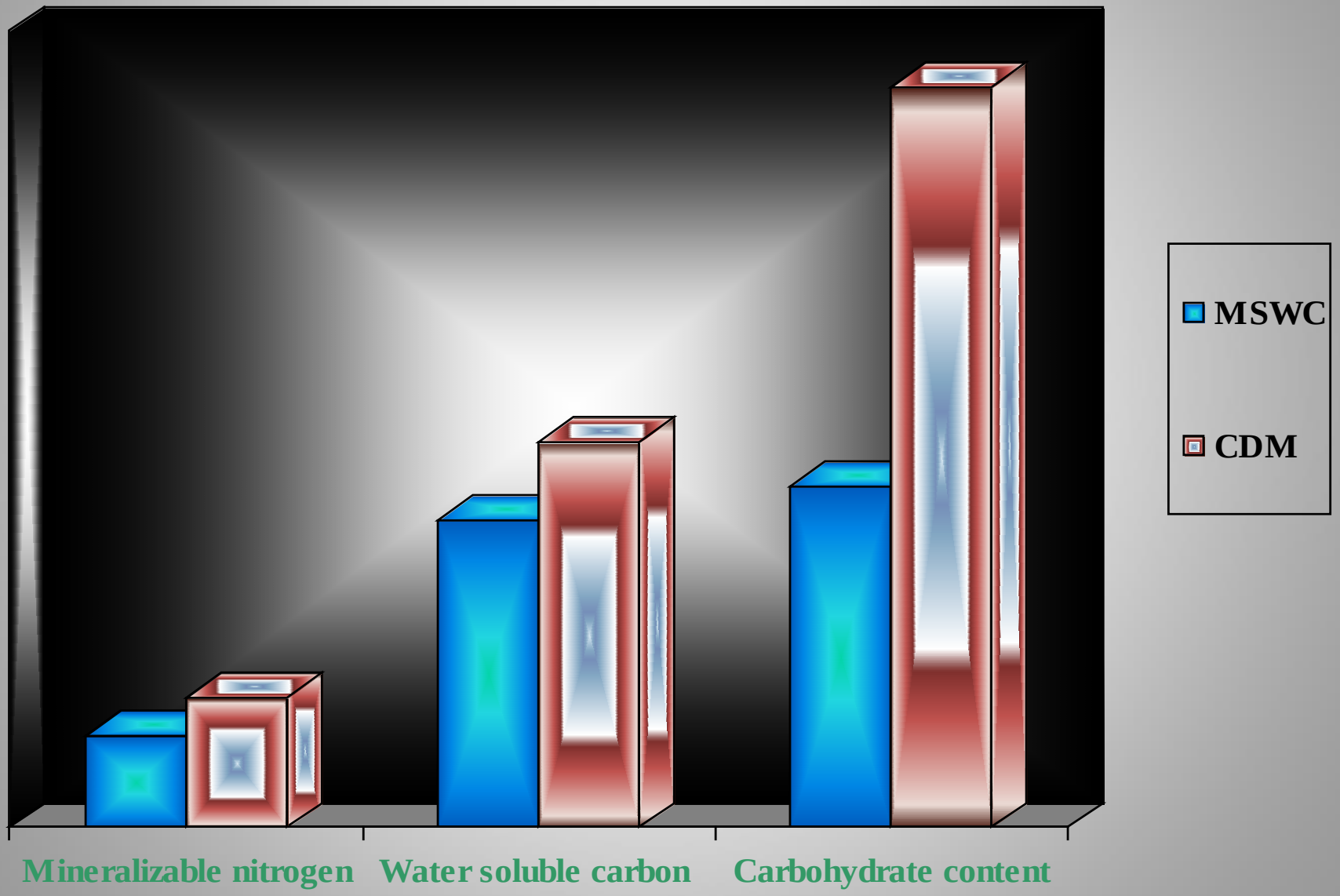
Straw and grain yields of rice as affected by the treatments



Nitrogen uptake by rice as affected by treatments in 1999



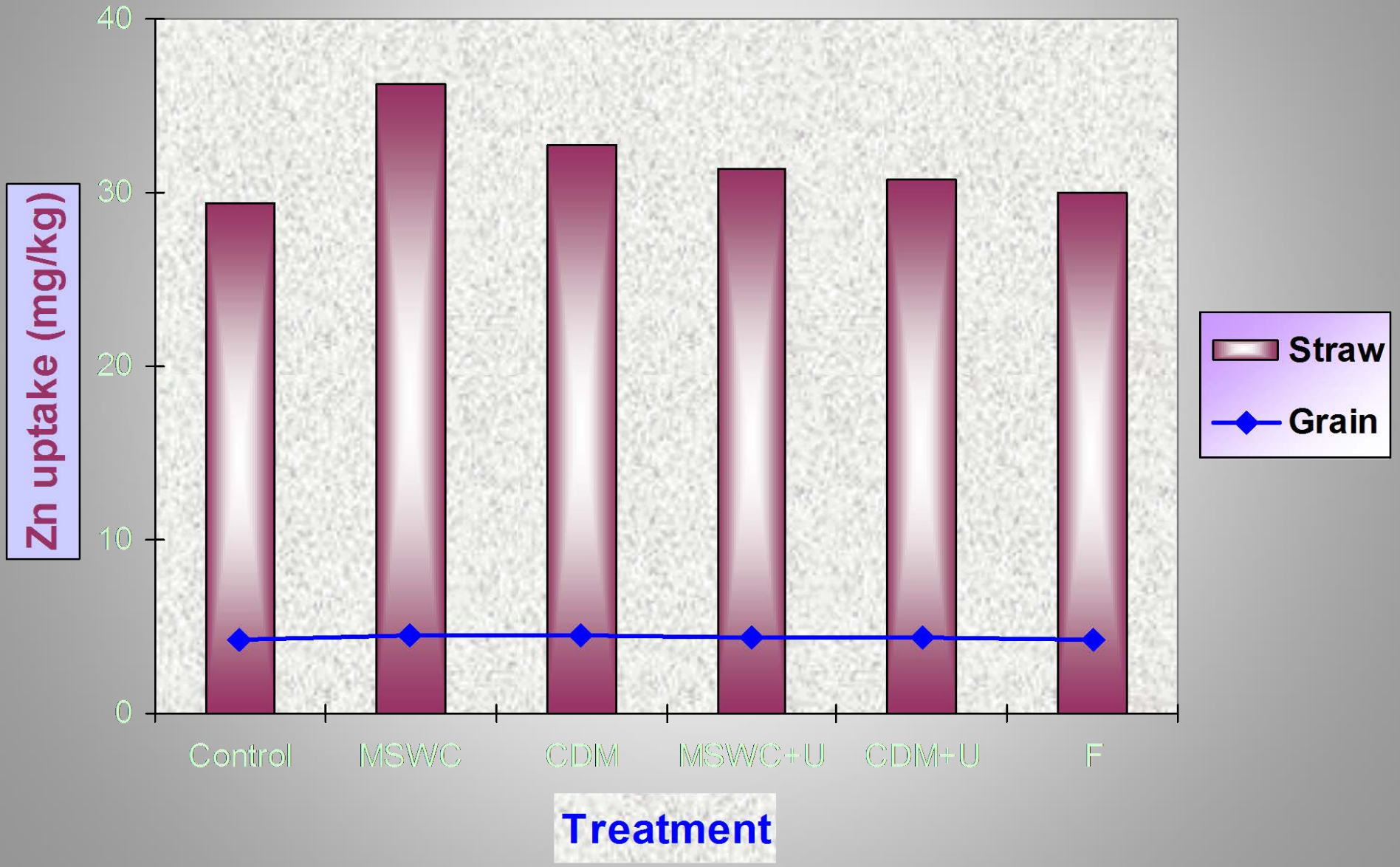
Organic matter quality parameters



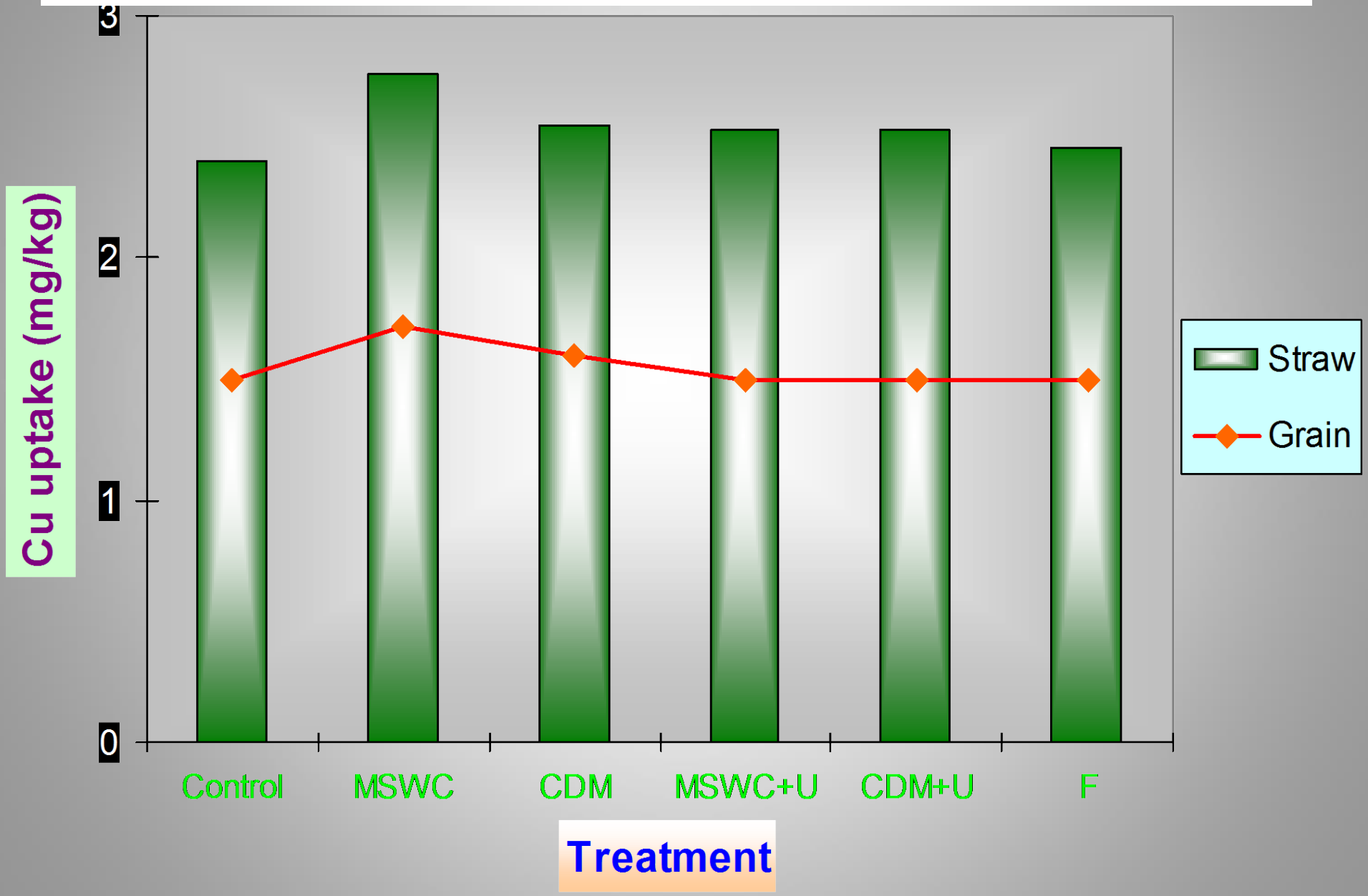
Physico-chemical properties of soil under different treatments after rice harvest

Treatment	pH	EC (dS/m)	WHC (%)	Organic-C (g/kg)	Total-N (g/kg)	C/N	CEC (cmol (p^+)/kg)	Av.P (mg/kg)	Av.K (mg/kg)
Control	5.6	0.23	62	13.5	1.60	8.4	18.9	5.7	100
MSWC	6.1	0.42	69	15.4	1.76	8.7	20.2	7.3	132
CDM	5.9	0.44	70	15.7	1.78	8.8	20.5	7.5	135
MSWC+U	5.9	0.38	68	15.1	1.74	8.7	19.9	7.7	122
CDM+U	5.7	0.40	68	15.3	1.76	8.7	20.1	7.9	126
F	5.6	0.34	62	13.6	1.74	7.8	19.4	7.4	131
Mean	5.8	0.37	66	14.8	1.73	8.5	19.8	7.25	124
LSD at 0.05P	NS	NS	NS	NS	NS	-	NS	NS	NS

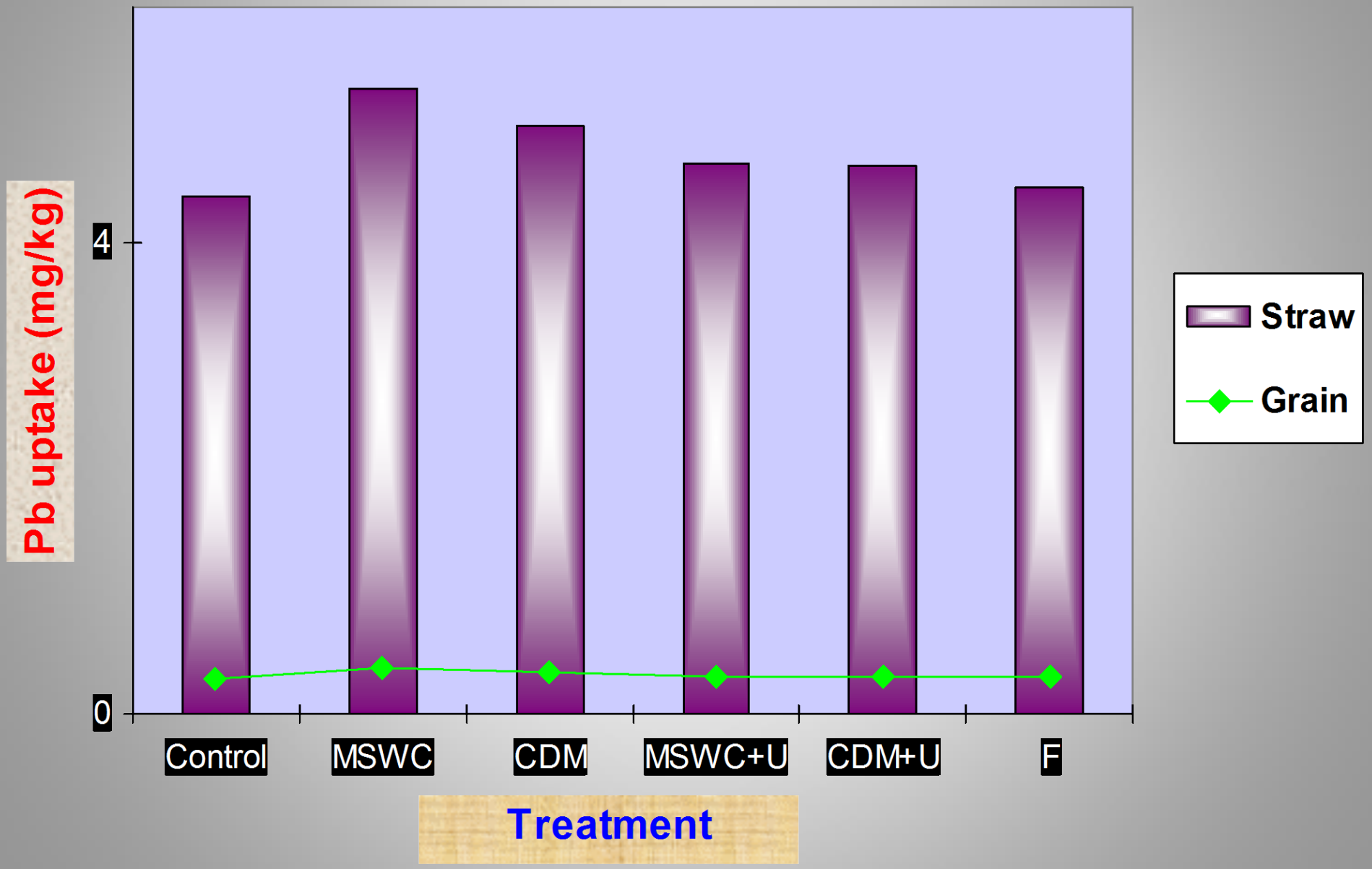
Zinc uptake (dry weight basis) by rice as affected by treatments



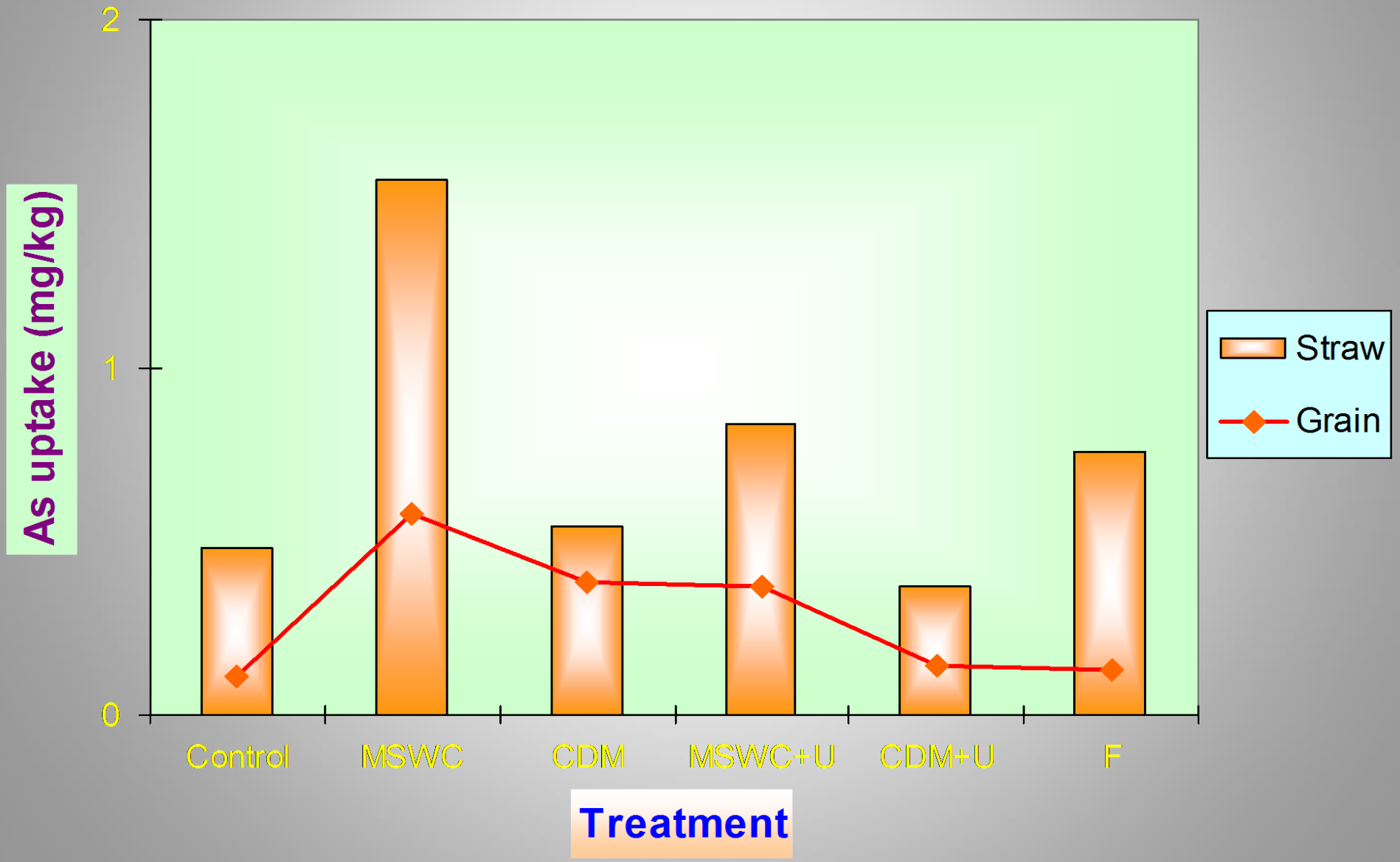
Copper uptake (dry weight basis) by rice as affected by treatments



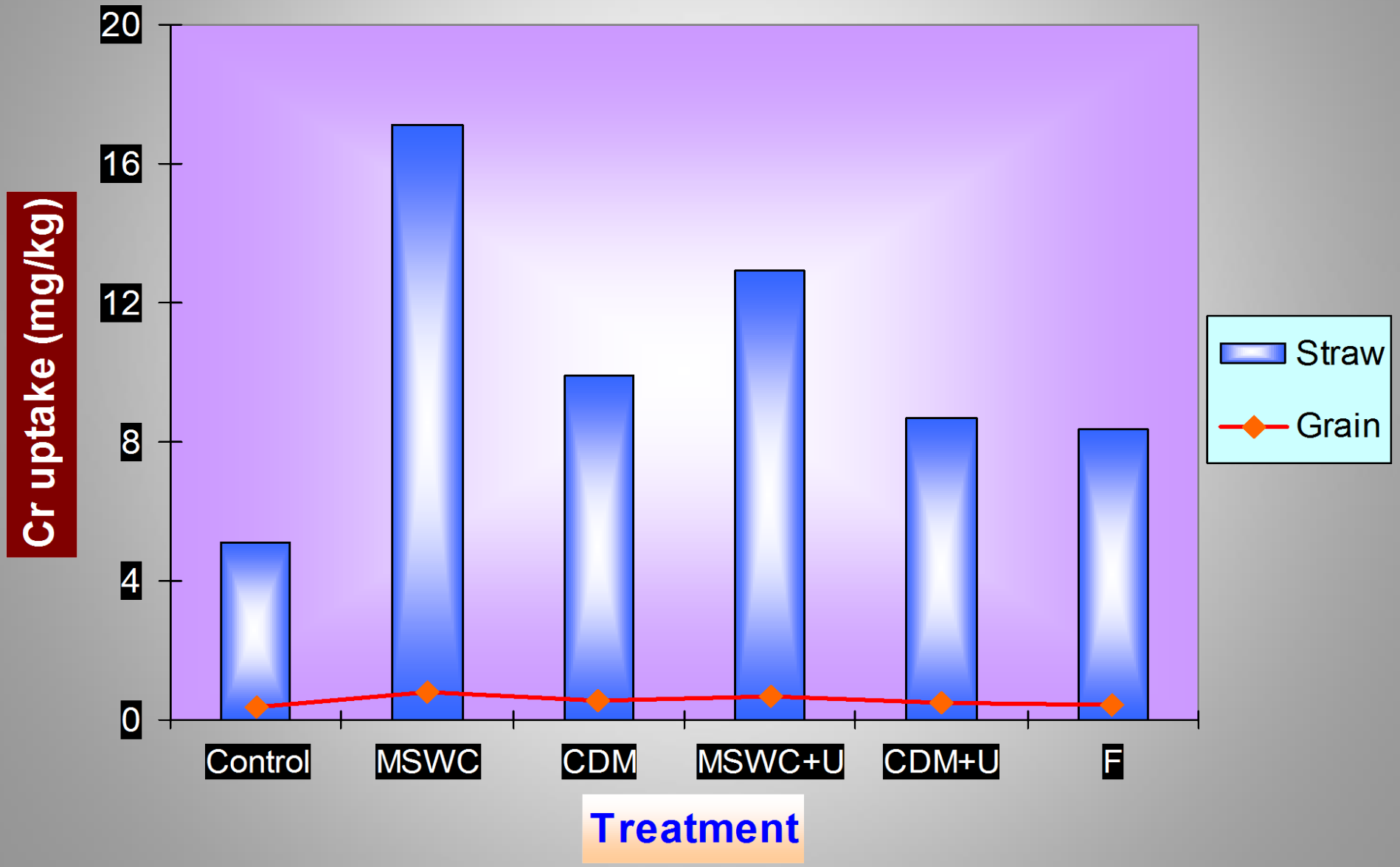
Lead uptake (dry weight basis) by rice as affected by treatments in 1999

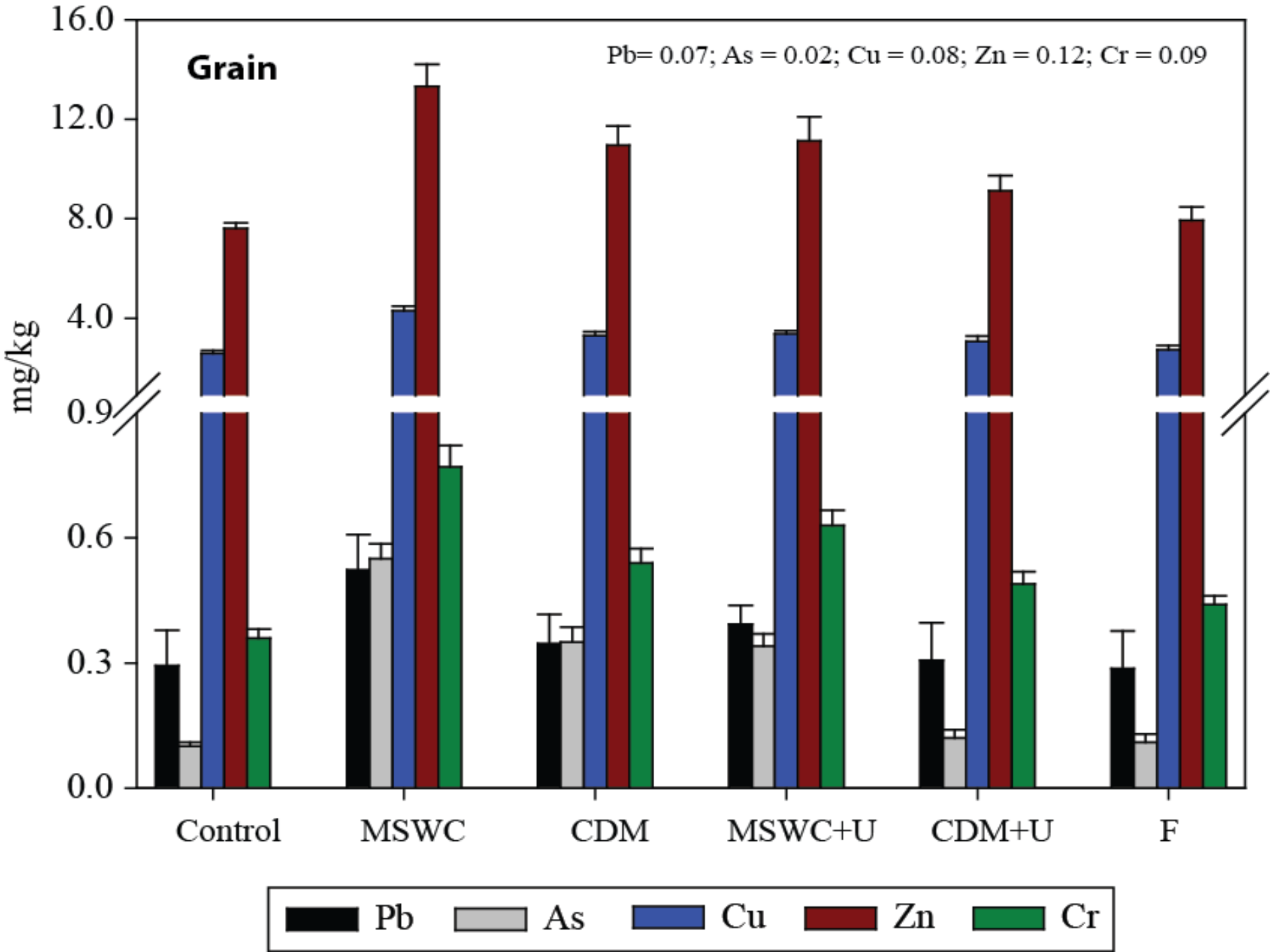


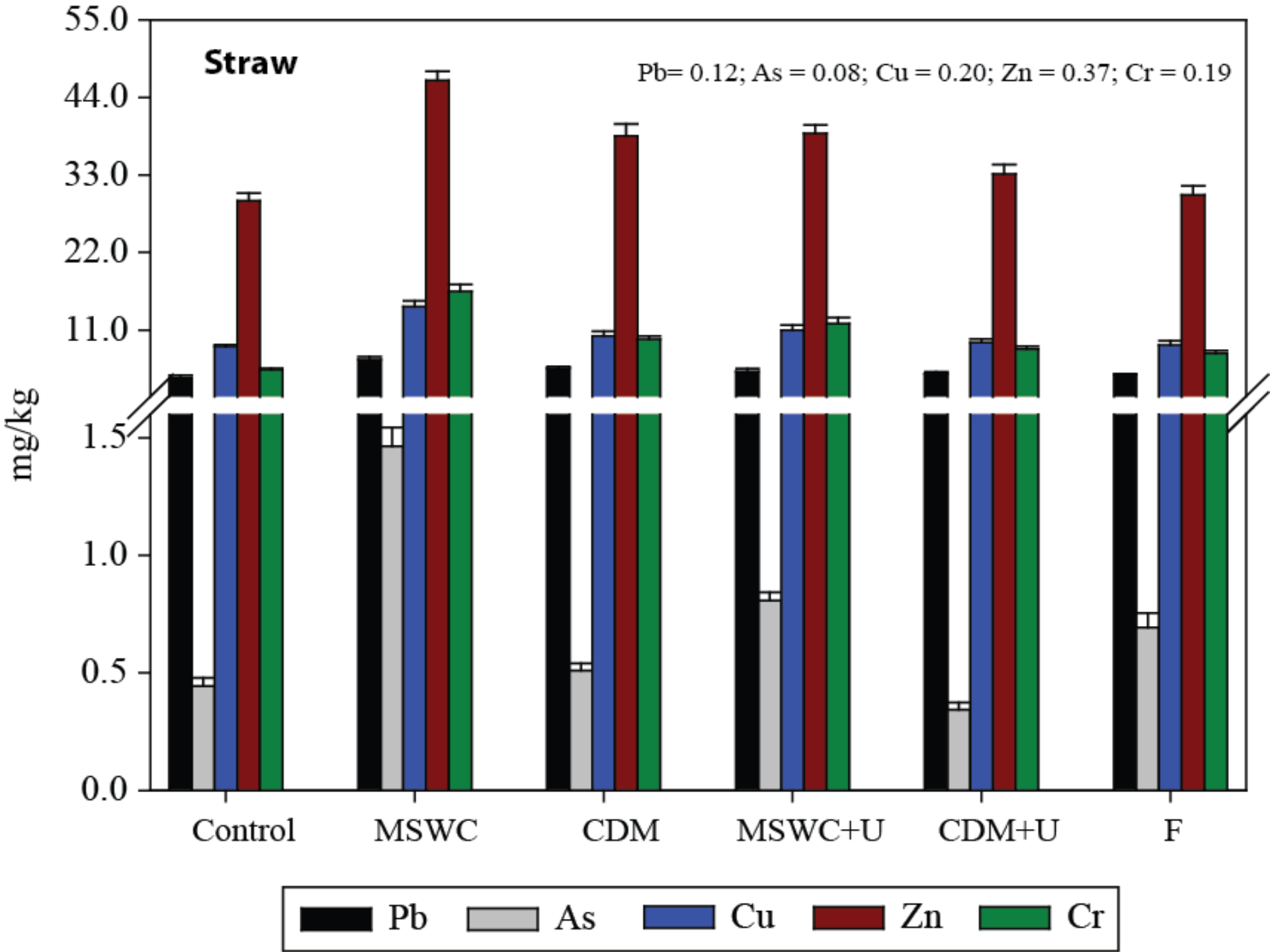
Arsenic uptake (dry weight basis) by rice as affected by treatments

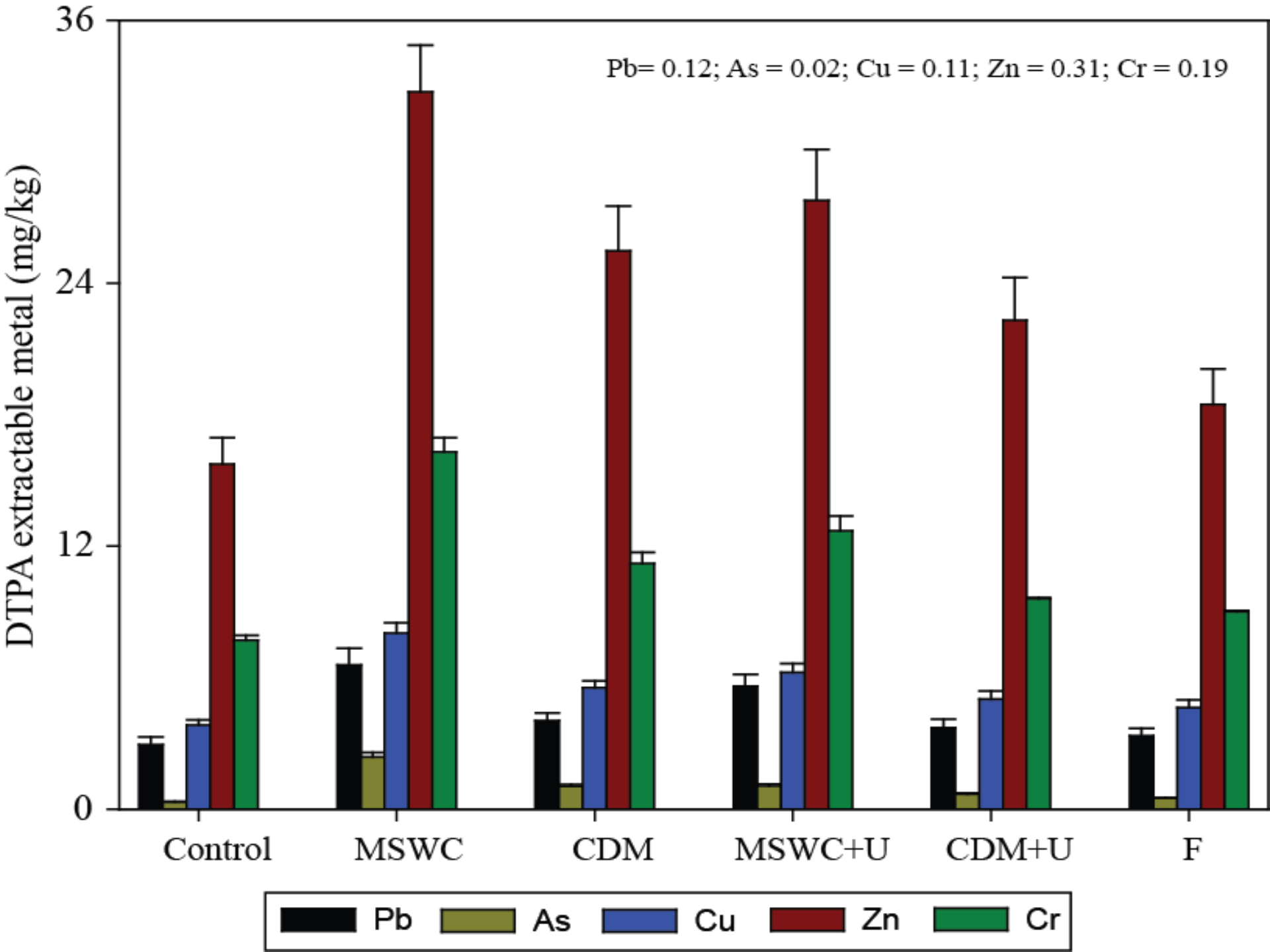


Chromium uptake (dry weight basis) by rice as affected by treatments




Grain
Pb= 0.07; As = 0.02; Cu = 0.08; Zn = 0.12; Cr = 0.09
mg/kg
16.0
12.0
8.0
4.0
0.9
0.6
0.3
0.0
Control
MSWC
CDM
MSWC+U
CDM+U
F
Pb
As
Cu
Zn
Cr


Straw
Pb= 0.12; As = 0.08; Cu = 0.20; Zn = 0.37; Cr = 0.19
mg/kg
55.0
44.0
33.0
22.0
11.0
1.5
1.0
0.5
0.0
Control
MSWC
CDM
MSWC+U
CDM+U
F
Pb
As
Cu
Zn
Cr


Pb= 0.12; As = 0.02; Cu = 0.11; Zn = 0.31; Cr = 0.19
DTPA extractable metal (mg/kg)
36
24
12
0
Control
MSWC
CDM
MSWC+U
CDM+U
F
Pb
As
Cu
Zn
Cr

Correlation coefficients (r) between metal fraction of MSWC and metal content (mg kg^{-1}) in rice grain treated with MSWC

Fraction of metal	Zn	Cu	Pb	Cr	As
Water soluble	0.63*	0.59*	0.65*	0.57*	0.62*
Exchangeable	0.66*	0.66*	0.58*	0.62*	0.59*
Carbonate bound	0.45	0.29	0.24	0.41	-0.06
Fe, Mn Oxide bound	0.79**	0.71**	0.73**	0.69**	0.71**
Organic Matter bound	0.41	-0.1	0.45	0.43	0.44
Residual	-0.39	-0.6	0.11	0.44	-0.50

* 5% level of significance; ** 1% level of significance

Correlation coefficients (r) between metal fraction of MSWC and metal content (mg kg^{-1}) in rice straw treated with MSWC

Fraction of metal	Zn	Cu	Pb	Cr	As
Water soluble	0.66*	0.58*	0.64*	0.57*	0.66*
Exchangeable	0.67*	0.63*	0.58*	0.64*	0.60*
Carbonate bound	0.41	0.21	0.13	0.19	-0.24
Fe, Mn Oxide bound	0.81**	0.77**	0.83**	0.69**	0.74**
Organic Matter bound	0.47	-0.3	0.52	0.48	0.44
Residual	-0.47	-0.33	0.29	0.18	-0.45

* 5% level of significance; ** 1% level of significance

Comparison between metal content (mg/kg) in grain and straw of rice of compost amended soil and normal soil*

Metal	Grain		Straw	
	Normal Soil	Compost amended	Normal Soil	Compost amended
Zn	15.5	4.50	68.3	36.2
Cu	3.3	1.72	45.6	2.76
Pb	0.8	0.39	57.1	5.0
Cr	3.0	0.77	30	16.5
As	5.0	0.55	100	1.42

*Source: Adriano (1992); Kabata_Pendius, 1992

CONCLUSION

- **Application of MSWC increased the dry matter production, yield and nitrogen uptake by rice plant. MSWC could be beneficially used as an organic supplement for wetland rice. Uptake of metal by rice grown with MSWC was within safe limits. The study indicated that the reducible Fe and Mn oxide bound fraction are more important for controlling the mobility and bioavailability of metal than the oxidisable organic matter bound fraction in rice paddies.**

- **Long-term field experiments with MSWC are needed to assess the environmental risk through regular monitoring of metal loads and accumulation in soil.**

Thank You