# HEAVY METAL POLLUTIONS IN PADDY SOILS AROUND HO CHI MINH CITY CAUSED BY WASTEWATER DISCHARGE AND THE INFLUENCE OF CADMIUM ON RICE

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## ABSTRACT

*Most of the industrial factories in Ho Chi Minh city haven't wastewater treatment systems. Wastewater flows directly into rice fields and pollutes water resources and the soil environment affecting agro production. This paper presents the results of a research on 6 heavy metals (Cd, Cu, Zn, Pb, Hg, Cr) at 126 points in rice fields including 14 wards and villages of districts No.2, No.7, No.9, Binh Chanh, Thu Duc and Nha Be. The research results showed that the paddy soil areas have been affected by industrial and household wastewater from HCMC with a great threat from Cd pollution. Concentrations of Cd in paddy soils ranged from 4.7 to 10.3mg/kg.*
*Addition of Cd to the soil with concentrations of 5-40mg/kg in dry soil showed that, Cd concentration in soil of over 25mg/kg affected agro-characteristics and yield factors. However, the influence depends on the rice variety. The content ratios of Cd in soil: roots: straw: brown rice were roughly 10:200:10:1. Accumulation of Cd in brown rice in field experiments was low (10-20%) compared to green house experiments. Although the Cd content was rather high in rice of some areas outside of HCMC, but it was still under the standard limitation.*

## Introduction

Ho Chi Minh City (HCMC) is the largest city in Vietnam. It is located in a special geographical position where many favorable conditions for economic development converge. The area of the city is 2,056km$^2$ and the population 5,225 million. It has the highest rate of development in industry and handicrafts in Vietnam. In 2000 HCMC had 1,000 industrial factories, 28,500 handicraft foundations and 12 industrial zones. Most industrial zones have been operating since before 1975. They now find themselves with outdated equipment and without wastewater treatment systems. The wastewater has been discharged into canals and flows directly down to cultivated areas causing a serious pollution and effecting on soil and agricultural water, especially on the rice-fields and aquaculture areas of the suburbs. Although the HCMC government carried out monitoring and assessment of heavy metals in river water, groundwater, sludge from rivers and canals, vegetation, aquatic life and so on, but heavy metal pollution in rice-fields and its influence on rice have not been studied. This research concentrated on 6 heavy metals (Cd, Cu, Zn, Pb, Hg, and Cr). They were analyzed in samples from 126 points of rice-fields polluted by wastewater from industrial and domestic activities. All of those points distributed over 14 wards and villages of 5 districts and counties, namely Nha Be and Binh Chanh Counties, District 2, District 7, District 9 and Thu Duc District.

## Equipment and methodology

The investigation, selection of areas and collection of samples were based on NESCAP and CCME methods. Soil samples were collected at rice-fields at the depth of 3-15cm. Soil samples were treated and kept in laboratory conditions. Heavy metals in soil were analyzed using the polarographic method and heavy metals in rice were determined by neutron activation. After analyzing 6 heavy metals in soils, we concluded that Cadmium has a high pollution potential for rice-fields in the areas investigated. Determination of the Cd influence in soil on the rice growth was firstly done with an experiment in which 6 rice plants were grown in the same pot with 4.5 kg of dried soil collected from investigated areas. Cadmium was added to these soils of the following concentrations: 0, 5, 10,15, 20, 25, 30, 35 and 40mg/kg. Filtered water was used for irrigation. Rice variety VND95-20, a popular variety, was used in the experiment, and was conducted in a green house in which humidity; temperature and light were standardized and controlled. We also observed the growth, development and the accumulation of Cd in rice in a confirmation experimental results and analysis of Cd in rice-grains, and rice at investigated Cadmium-polluted areas with two rice varieties VN95-20 (high production rice) and VD20 (aromatic rice). Soil samples were collected at Nha Be County and 5 levels of Cadmium were applied: 0, 15, 20, 25, and 30mg/kg dried-soil. Mixed soil was poured into square wooden trays (100x100x30cm) with nylon liner large enough for thirty rice plants per tray. Data were analyzed by ANOVA standardization using MSTATC and IRSTAT 4.01

## Results and discussion

Analysis results of 6 heavy metals (Cd, Cu, Pb, Hg, Zn, and Cr) from 126 sampling points of rice-fields directly polluted by wastewater from HCMC are presented in Table 1. The results showed that, Cr and Pb indicated some levels of pollution, they are just slightly in excess of accepted limits compared to standards of some European countries. Hg and Cu were within limits, and was lower than standard permission (TCCP). The concentration of Zn was high in some cultivated areas, especially near some factories and industrial zones. Cd showed remarkable accumulations in soil with high concentrations from 9.9 to 10.3 mg/kg, this being as high as twice the standard permission.

Table1. Concentration of heavy metal in paddy soil polluted by wastewater from HCMC (mg/kg)

| Places | No. samples | Cd | Cu | Zn | Pb | Hg | Cr |
|---|---|---|---|---|---|---|---|
| Dist. 2 | 10 | 5.5 | 33.1 | 435 | 43.6 | 0.34 | 44.8 |
| Dist. 7 | 4 | 4.7 | 22.7 | 233 | 39.0 | 0.05 | 115.4 |
| Dist. 9 | 6 | 4.9 | 29.5 | 568 | 40.5 | 0.03 | 54.3 |
| Nha Be | 88 | 9.9 | 28.6 | 110 | 61.7 | 0.09 | 125.3 |
| Binh Chanh | 10 | 10.3 | 31.0 | 197 | 58.0 | 0.21 | 119.0 |
| Thu Duc | 8 | 6.8 | 30.0 | 282 | 44.3 | 0.20 | 84.3 |
| Standards of some countries | | | | | | | |
| Holland | | 1-5* | 50-100 | 200-500* | 50-150* | 0,5-2 | 100-250* |
| England | | 1-3 | 140 | 280 | 35 | 0 –1 | 0-100 |
| Germany | | 3+ | 100+ | 300+ | 50+ | 2+ | 100+ |

The Center for experimental analysis (1996) reported that Cd in mud of the Nhieu Loc-Thi Nghe canal fluctuated between 28-35 mg/kg and the Institute for Environment and Resources (1998) reported that the average Cd concentration in the Sai Gon-Dong Nai river system was between 9.7-25 mg/kg. Also, Cd concentration in spinach fields at Vinh Loc, Binh Chanh County was 5.09mg/l (Bui Cach Tuyen, *et al*., 1994). Cadmium is one of the 8 elements that polluted the sludge of the Tan Hoa - Lo Gom canals (Ngo Quang Huy, *et al*. 1999).

A study of 8 soil categories in Nha Be County (Table 2) showed that Zn and Cd occurred with high concentrations in 3 soil types namely Pfm, Ppm and Sj2m. For the other 5 categories, the concentration of Cd and Zn decreased with the distance from the pollution source (Kuo, S., Heilman, P.E. and Baker 1983).

Table 2. Distribution of heavy metals in some soil types in the research areas (mg/kg)

| No. | Soil type. | Cd | Cu | Zn | Pb | Hg | Cr |
|---|---|---|---|---|---|---|---|
| 1 | Red-Yellow alluvial soil (Pfm) | 16.7 | 27.5 | 130.0 | 78.1 | 0.19 | 133.1 |
| 2 | Alluvial soil/ potential acid sulfate soil (Ppm) | 14.0 | 29.4 | 102.4 | 63.8 | 0.07 | 136.5 |
| 3 | Actual acid sulfate soil ($Sj_2m$) | 14.5 | 28.7 | 102.1 | 66.8 | 0.15 | 133.8 |
| 4 | Actual acid sulfate soil ($Sj_2m$) | 7.6 | 23.6 | 83.8 | 70.2 | 0.12 | 124.3 |
| 5 | Actual acid sulfate soil, read rusts ($Sj_2Rm$) | 12.4 | 27.7 | 92.7 | 59.4 | 0.12 | 129.7 |
| 6 | Actual acid sulfate soil, depth layer ($Sp_2m$) | 7.8 | 18.6 | 97.2 | 67.1 | 0.11 | 121.3 |
| 7 | Potential. AAS, Shallow acid layer ($Sp_1m$) | 8.0 | 30.0 | 99.0 | 76.3 | 0.09 | 140.5 |
| 8 | Potential. AAS, many organic ($Sp_1hm$) | 8.0 | 23.2 | 87.7 | 71.2 | 0.08 | 120.5 |

Figures in Table 3 showed that with an increasing concentration of Cd in soils, rice would need a longer time to grow. This is explained by the fact that a high concentration of Cd in soil poisons the roots of the rice plants. A Cd concentration in soil above 20 mg/kg will restrict the growth process of rice, and decrease the length of the rice plant. This in turn leads to a decrease in biomass.

Table 3. Effect of Cd on the agro-characteristics and the dry yield of rice

| Cd (mg/Kg) | Duration (days) | Plant length (cm) | Dried biomass (g/pot)(*) |
|---|---|---|---|
| 0 | 108 | 82.8 | 17.7 |
| 5 | 107 | 84.0 | 17.4 |
| 10 | 107 | 80.2 | 17.2 |
| 15 | 106 | 79.7 | 16.5 |
| 20 | 108 | 76.2 | 15.6 |
| 25 | 110 | 70.8 | 14.4 |
| 30 | 113 | 61.2 | 13.6 |
| 35 | 115 | 60.7 | 13.3 |
| 40 | 116 | 60.0 | 11.7 |
| Cv (%) | - | 2.48 | 10.02 |
| $LSD_{0,01}$ | - | 4.85 | 4.19 |

(*) at 64 days after growing

Results in Table 4 showed that a high concentration of Cd in soil decreased the number of panicles per pot, with Cd concentration higher than 30 mg/kg causing a decrease of more than 40%. Table 4 also showed that Cd concentration in soil between 25-30 mg/kg and 35-30 mg/kg would cause productivity decrease about 31.6-32.0 % and 40.1-53.8 %, respectively.

Provide that to confirm the results, the project carried out field experiments with 5 different Cd concentrations of 0, 15, 20, 25 and 30 mg/kg on 2 types of rice (VND950-20 and VD20).

Table 4. Effect of Cd on the number of panicles and the rice yield

| Cd (mg/kg) | panicle /pot | P.1000 seed (g) | Husky (%) | Yield (g/pot) | % compared to control |
|---|---|---|---|---|---|
| 0 | 17.0 | 23.6 | 29.2 | 29.6 | 100.0 |
| 5 | 16.0 | 23.2 | 30.2 | 30.6 | 103.6 |
| 10 | 15.0 | 22.8 | 29.5 | 27.1 | 91.6 |
| 15 | 13.7 | 22.8 | 31.7 | 24.0 | 81.2 |
| 20 | 11.7 | 21.7 | 35.3 | 23.7 | 80.3 |
| 25 | 11.7 | 20.5 | 35.8 | 20.1 | 67.9 |
| 30 | 11.0 | 20\.5 | 42.2 | 20.2 | 68.4 |
| 35 | 9.7 | 19.9 | 50.2 | 17.7 | 59.9 |
| 40 | 9.0 | 19.4 | 44.4 | 13.6 | 46.2 |
| Cv (%) | 12.26 | 8.56 | 8.01 | 5.49 | - |
| $LSD_{0.01}$ | 4.28 | 2.83 | 8.01 | 3.47 | - |

Figures in Table 5 showed that with VD20 rice variety, the number of panicles/m$^2$ decreased at the Cd concentration of 15 mg/kg, meanwhile VND95-20 had not clear influence at this concentration. At the concentration 25 mg/kg, the number of empty rice-grains per panicle in VND95-20 rice increased and above 30 mg/kg this happened in VD20 rice.

At the concentration above 20 mg/kg, the productivity of VND 95-20 rice decreased to about 630-1730 kg/ha while the productivity of VD20 decreased only at concentration above 30 mg/kg.

Table 5. Effect of Cd on the yield of the aromatic rice VN20 and the high yielding VND95-20

| Cd (mg/kg) | Panicles/m$^2$ | | Grains /Panicle | | Yield (ton/ha) | |
|---|---|---|---|---|---|---|
| | VND 95-20 | VD20 | VND 95-20 | VD20 | VND 95-20 | VD20 |
| 0 | 225 | 214 | 99 | 129 | 5.31 | 4.51 |
| 15 | 203 | 182 | 101 | 132 | 4.90 | 4.53 |
| 20 | 200 | 168 | 100 | 122 | 4.68 | 4.35 |
| 25 | 217 | 171 | 77 | 136 | 3.90 | 3.13 |
| 30 | 202 | 165 | 73 | 104 | 3.58 | 3.77 |
| CV (%) | 7.10 | | 8.98 | | 8.33 | |
| $LSD_{0,05}$ | 22.13 | | 15.40 | | 5.82 | |

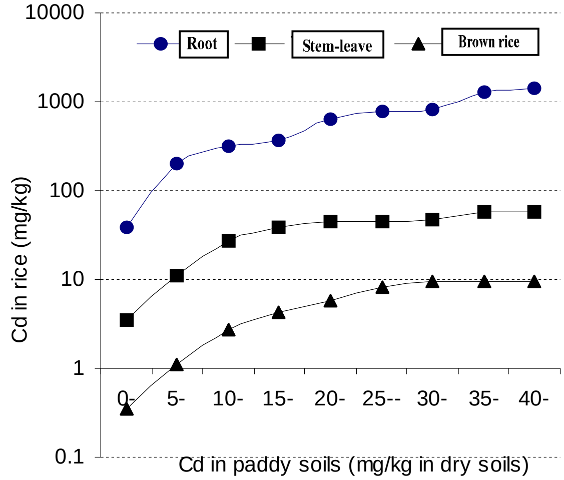


fig.III.7: Relationship betw een Cd in soil and accumulation of Cd in deferent parts of rice

Standard of Cd in raw grains ≤ 1 mg/kg

Results in figure 1 showed that, the concentration of Cd accumulated in different parts of the rice plant as a result of cadmium uptake from soils. Accumulations are highest in roots, about 20-30 times higher than in stems and leaves and about 100-200 times higher than in grains. Roughly this translated in the ratio of Cd in soil: roots : stems and leaves : rice grains of 10:200:10:1.

Results in figure 1 also showed that, at the same Cd level in soil, the accumulative capacity of Cd in husked rice in the fields is much lower compared to that in the greenhouse.

## Conclusions and recommendations

- Rice fields around HCMC have been polluted by wastewater at level of several heavy metals, especially Cd. Concentrations of Cd soil ranged from 4.7 to10.3 mg/kg, and at some locations are 2 or 3 times higher than the standard permission.
- Cadmium accumulates easily in red-yellow alluvial, acid sulfate, alluvial and actual acid sulfate soils.
- Cadmium concentration above 25 mg/kg affected agronomical characteristics and caused decreases of rice productivity. The influence had different degrees on different rice cultivars.
- Increasing the Cd concentrations in soils leaded to higher Cd accumulation in rice. The ratio of Cd in soil : Cd in roots : Cd in stems and leaves : Cd in husked rice is approximately 10:200:10:1.
- The accumulation of Cd in rice in the fields is much lower than in the greenhouse experiments.
- Rice grown in areas affected by high Cd wastewaters in HCMC did not show strongly elevated Cd levels in grains, and is generally well within the standard permission.

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