SustaiN 2013

The 4th International Conference on

Sustainable Future for Human Security

[SustaiN 2013]

CONFERENCE PROCEEDING

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The 4th International Conference on Sustainable Future for Human Security SUSTAIN 2013

Editorial

The 4th International Conference on a Sustainable Future for Human Security (SUSTAIN 2013) was held at Kyoto University (Japan) on 19-21 October, 2013. The conference was organized by SustaiN Society and the Indonesian Students Associations of Kyoto, with the support of the Organization for the Promotion of International Relations (OPIR) Kyoto University, Research Institute for Sustainable Humanosphere (RISH), Global Center for Education and Research on Human Security Engineering (HSE), Global COE Program for Sustainability / Survivability Science for a Resilient Society Adaptable to Extreme Weather Conditions (GCOE-ARS), and Inter-Graduate School Program for Sustainable Development and Survivable Societies (GSS).

The conference originated from the need to provide an inter-disciplinary forum where the most serious problems affecting a sustainable future for human security could be discussed, in recognition of the fact that many future problems cannot be solved by a "siloed" approach. The emphasis on sustainable futures is in response to the general awareness of the need to solve numerous human-related problems resulting from the rapid growth of modern society. The topic of sustainable futures for human security needs to be discussed in an integrated way, in accordance with the principles of sustainability, considering energy and materials supply, economies and trade, technology, cities, agriculture, social and environmental aspects.

To continue providing adequate technology to cope with the demands of human quality of life requires intensive research and development with multidisciplinary perspectives. Research and development towards achieving future human security should embrace sustainability perspectives, to avoid negatively impacting the environment and necessitating or exacerbating inefficient use of natural reserves, increasing emissions and hazardous wastes and jeopardizing human health and society.

The conference covered a wide range of issues with the aim of highlighting potential issues and paths towards a sustainable future. It attracted a high level of attendance from countries of the global North and South, with a wide geographical coverage. Overall, 160 participants were involved, with 120 presentations over the course of the conference. The quality of papers received was a testament to the reputation that the conference has been building over the past 3 years.

Papers presented at SUSTAIN 2013 were divided into five thematic areas: (1) Energy and Environment (EnE); (2) Sustainable Forestry and Agriculture (FA); (3) Sustainable Built Environment in Tropical Hemisphere Countries (BE); (4) River Basin and Disaster Management (RnD); (5) Social Science and Economics (SE). Under these broad areas, a wide-ranging series of presentations was given, which elaborated on current research across Asia and the world. Being held in Kyoto, a city of great cultural heritage, the participants also took part in a tour of some of the main sights and experiences that link modern and ancient Japan.

The two programmed days of the conference each commenced with keynote presentations which, like the conference itself, were wide-ranging. In the first session on day one, Dr. Ir. Edi Effendi Tedjakusuma, delivered an address on issues of a sustainable future for human security in the context of Indonesia. Dr. Puppim de Oliveira, Assistant Director and Senior Research Fellow at the United Nations University Institute of Advanced Studies (UNU-IAS), then discussed the future sustainability of cities in Asian nations. In the last keynote, Professor Satoshi Fujii, a Japanese cabinet adviser on Disaster Prevention and Reduction, introduced Japanese policy towards a more resilient country.

The organizers appreciate the support and assistance of the co-operating organizations, the participants, presenters and staff. The next SUSTAIN conference is highly anticipated by all the attendees of SUSTAIN 2013 and the committee expect to further build on the success of this year's event.

Selection and peer-review under responsibility of the SustaiN conference committee and supported by Kyoto University; (RISH), (OPIR), (GCOE-ARS) and (GSS) as co-hosts.

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Status of Heavy Metal Concentration in Water of Citarum River at Selected Sites in Bandung Residence

Eka Wardhani

Environmental Engineering Department, Institut Teknologi Nasional (Itenas) Bandung
Jalan P.H.H Mustofa 23 Bandung 40123 West Java IndonesiaTel:+62-22-7272215, Fax: +62-22-7202892
E-mail: ekw_wardhani@yahoo.com

Abstract

The pollution of aquatic ecosystem by heavy metals has been assumed as serious proportions due to their toxicity and accumulative behavior. This paper deals with the measurement of four heavy metals, i.e. Cd, Cr^{6+}, Cu, and Zn. Grab samples of water for one year period (March, June, and November) were collected from 6 different sites following the Standard Methods. Water samples of this river ware processed and analyzed for heavy metal using AAS. The heavy metal found in the river water were in range of: Cd (0.00 to 0,01 mg/L); Cr^{6+} (0.03 to 0.18 mg/L); Cu (0.00 to 0,08 mg/L); and Zn (0.00 to 1.44 mg/L). Some physic-chemical parameters which were dissolved oxygen, BOD_5, and COD were also estimated as they have direct or indirect influence on incidence, transport and speciation of the heavy metals. Based on the findings, the Citarum river water can be considered as polluted with respect to Cd, Cu, Cr^{6+}, and Zn.

Selection and peer-review under responsibility ofthe SustaiN conference committee and supported by Kyoto University; (RISH), (OPIR), (GCOE-ARS) and (GSS) as co-hosts.

Keywords: Accumulative Heavy metals; Citarum Rivers; Pollution;toxicity;

1. Introduction

The Citarum River is one of the most utilized rivers in Indonesia. Due to the abundant availability of water throughout the year, it has played an important role in the development of West Java civilization and economy. Increased urbanization and industrialization in the basin has resulted in polluting the river, since the river has been the preferred waste disposal site for industrial and domestic effluents.

The Pollution of aquatic ecosystem by heavy metals has assumed to be serious proportions due to their toxicity and accumulative behavior. Unlike organic pollutants, natural processes of decomposition do not remove heavy metals. Metals are introduced into the aquatic system as a result of weathering soil and rocks from volcanic eruptions and from a variety of human activities involving mining, and processing use of metals or substances containing metal contaminants. Trace metals entering natural water become part of the water-sediment system and their distribution processes are controlled by a dynamic set of physicochemical equilibrium. The metal solubility is principally controlled by pH, concentration and type of ligands and chelating agents, oxidation-state of mineral components and the redox environment of the system.

Since each form may have different bioavailability and toxicity, the environmentalists are rightly concerned about the exact forms of metal present in the aquatic environment. Thus, distribution of heavy metals in water, and sediments play a key role in detecting sources of heavy metal pollution in aquatic ecosystem [5]. Almost all important rivers in West Java have been monitored in detail for heavy metal pollution in water. However, very little emphasis has been given on the heavy metals accumulation in Citarum River water, especially in the region of Bandung residences.

In this paper, we presented the heavy metals distribution in Citarum River and quantified the degree of pollution caused by them at this stretch. Metals in the Citarum River come from natural as well as artificial sources. Metal that is naturally introduced into the river is primary from sources, such as rock weathering, soil erosion, or the dissolution of water-soluble salts. Naturally occurring metal moves through aquatic environments of human activities independently. Usually, it is without any detrimental effects. However, as the valley of the Citarum River and its tributaries are settled and industrialized, the metal are essential for proper metabolism an all living organism yet toxic at high concentrations. Other metals currently thought of as non-essential are toxic even at relatively low concentrations.

Heavy metals are released to the Citarum River from numerous sources. Typical sources are municipal wastewater-treatment plants, manufacturing industries, mining, and rural agricultural cultivation and fertilization. Heavy

metals are transported as either dissolved species in water or as an integral part of suspended sediments. Heavy metals may be volatilized to the atmosphere or stored in riverbed sediments. Toxic heavy metals are taken up by organism; the metals dissolved in water have the greatest potential of causing the most deleterious effects [7][9].

2. Material and Methods

2.1. Description of Study Area

Citarum River is the biggest river in West Java Indonesia. It has an important role in the lives of the people of West Java as it is used to support agriculture sector, water supply, fishery, industry, sewerage, electricity, etc. There are three hydroelectric power plant dams installed along this river: Saguling, Cirata, and Ir. H. Djuanda (Jatiluhur) hydroelectric power plant, all supplying the electricity for Bandung and Greater Jakarta area. The Jatiluhur Dam with a 3 billion cubic meter storage capacity is the largest reservoir in Indonesia. The river is heavily polluted by human activities; about five million people live in the river's basin, and most of them rely on its flow for their water supply [9].

Majalaya in Bandung Residential is the heartland of the textile industry in Indonesia. Out of 600 factories built along the Citarum River, 170 are located in the village. Yet, 90 percent of the factories lack efficient waste water treatment systems. Industry sector discharge at least 1,320 Liters or 280 tons of waste everyday in the river and its tributaries [9].

2.2 Water Sampling

For water sampling, six sampling points were chosen at the banks of Citarum River. The sampling points were located at Bandung resident (see Table 1). These points were chosen because they receive considerable amount of wastewater from industrial areas well as from intensively cultivated agriculture areas and domestic wastes from 5 towns and villages (used as reference points), i.e.: Bandung, Sumedang, West Bandung Resident, Bandung and Cimahi Municipals.

Table 1. Location of the study sites in Citarum River

Site		X (meter)	Y (meter)
I	Cisanti Lake (Up Stream)	793709*	9202411*
II	Cikapundung	790729*	9226616*
III	Cisangkuy	789994*	9226634*
IV	Cibeureum	780601*	9229399*
V	Cibaligo	780159*	9232216*
VI	Cimahi	779133*	9232531*

*Universal Transverse Mecartor (UTM) coordinat system, zone 48 M

Six water samples were collected once in three times, i.e. in March, June, and November 2011. Water samples were taken using Van Dorn plastics bottles (1,5 L capacity). The samples, after collection, were stored in the refrigerator at about 4°C prior to analysis. All chemicals used in the study were of analytical grade and obtained from Merck Indonesia. Double distillated water was used throughout the study. The sample bottles were soaked in 10% HNO_3 for 24 hours and rinsed several times with double distilled water prior to use. All the glassware and other samples containers were thoroughly cleaned and finally rinsed with double distilled water. The pH measurement was made using pH meter (Model-Systolic 365); the metal concentration in the samples was determined using atomic absorption spectrophotometer (AA-3600 Shimadzu North America). The physicochemical parameters samples were determined following the standard methods for the analysis of water APHA [4]. Samples were analyzed in Environmental Engineering Laboratory of ITENAS Bandung.

3. Result and Discussion

3.1. Sources of Metals in the Citarum River

Heavy metals in the Citarum River are originated from either natural processes or human activities. Natural erosion and weathering of crusted materials take place over long periods of time and the amount of heavy metals released is small. However, the potential for contamination is increasing when mining exposes metal-bearing ores.

When compared to the natural exposure of ore bodies through erosion, the exposure rate through industry is over ten times faster for lead and zinc [6].Industrial wastewater can introduce substantial amounts of metals into the river. The largest amount of industries in the West Java is located along the Citarum River.

3.2 Physicochemical Characteristics of River Water

The pH ranged from 6.2 to 8.5 in all locations. The pH value of Citarum River water fell between slightly acidic to moderately alkaline and had relationship with the solubility and accumulation of heavy metal in river water according to Tessier et al and Warren and Zimmerman [35]. Dissolve oxygen ranged from 0.14 to 8.12 mg/L which was below as well as above the permissible limit assigned by Base International Standard (BIS). Biochemical Oxygen Demand (BOD_5) ranged from 1 to 202 mg/L which was above the WHO [34] limit of 3 mg/L, indicating that the water of all sites as polluted, which might affect the aquatic ecosystem. Chemical Oxygen Demand (COD) ranged from 2 to 492 mg/L. The values of physicochemical parameters measured in Citarum River water at different sites are given in Table 2.

Table 2.physicochemicaCharacteristics of Citarum River

No.	Site	Month	Q (m^3/s)	DO (mg/L)	BOD_5 (mg/L)	COD (mg/L)
	Cisanti Lake	March	0.12	7.34	2.00	2.00
I		June	0.19	7.80	1.00	2.00
		November	0.20	8.12	1.00	2.00
Average			0.17	7.75	1.33	2.00
	Cikapundung	March	4.35	3.42	18.00	23.00
II		June	6.14	4.40	24.00	56.00
		November	5.90	0.79	11.00	12.00
Average			5.46	2.87	17.67	30.33
	Cisangkuy	March	11.25	5.42	4.00	19.00
III		June	7.98	4.04	3.00	25.00
		November	30.00	3.44	2.00	2.00
Average			16.41	4.30	3.00	15.33
	Cibaligo	March	0.59	2.02	202.00	492.00
IV		June	0.45	0.48	162.00	440.00
		November	0.63	0.10	69.00	273.00
Average			0.56	0.87	144.33	401.67
	Cimahi	March	1.56	2.95	17.00	39.00
V		June	0.83	0.97	17.00	54.00
		November	0.52	4.83	13.00	22.00
Average			0.97	2.92	15.67	38.33
	Cibeureum	March	0.50	0.10	35.00	115.00
VI		June	0.36	0.10	66.00	158.00
		November	0.20	0.10	10.00	42.00
Average			0.35	0.10	37.00	105.00

3.3 Heavy Metals in the Citarum River

Cadmium in Citarum River

Cadmium has an atomic number of 48, an atomic weight of 112.40, consisting of eight stable isotopes ($^{112,114}Cd$ are most abundant), and a density of 8.65 g cm^{-3}[27]. In several aspects, Cd is similar to Zn (it is a neighbor of Zn in the

periodic table); in fact, it is almost always associated with Zn in mineral deposits and other earth materials. Cadmium is a soft, silvery white, ductile metal with a faint bluish tinge. It has a melting point of 321ºC and a boiling point of 765ºC. It belongs to group IIb of elements in the periodic table and in aqueous solution has the stable 2+ oxidation state. Cadmium is a rare element (67th element in order of abundance) with a concentration of ~0.1 µg/gin the lithosphere and is strongly chalcophilic, like Zn.

In nature, aerobic freshwater aquatic system with typical Cd- S–CO_2concentrations [18], $Cd^{2+}$is the predominant species below pH 8, $CdCO_3$ which is predominant from pH 8 to 10, and $Cd(OH)_2$is dominant above pH 10. The solubility of Cd is minimum at pH 9.5 [18]. The speciation of Cd is generally considered to be dominated by dissolved forms, except in cases where the concentration of suspended particulate matter is high, such as "muddy" rivers and reservoirs and near-bottom benthic boundary layers, and underlying bottom sediments in rivers and lakes [24]. The distribution coefficient between the particulate and the dissolved Cd is remarkably consistent for a wide range of riverine and lacustrine situations [25]. The sorption of Cd on particulate matter and bottom sediments is considered to be a major factor affecting its concentration in natural waters [15]. Pickering (1980) has quantitatively evaluated the role of clay minerals, humic substances, and hydrous metal oxides in Cd adsorption and concluded that some fraction of the particle-bound Cd was irreversibly held by the solid substrate[28]. The concentration of dissolved Cd in average world river water is 0.08 µg/L [14]. This concentration is identical to that of Cd in ocean water (0.079 µg/L)[10].

Cadmium was mostly absent in river water of Citarum during the study period. The concentration of heavy metals in river water of River Citarum did not show a definite seasonal behavior as well as site trend. However, overall order of concentration of these elements in river water was Zn>Cr>Cu>Ni>Cd. Thus, the higher concentration of Zinc and Chromium in river water presented an alarming picture in this area of river Citarum. Major pollution sources of River Citarum at this stretch were due to the entry of heavy load of city, sewage street washing and waste from automobile workshops and hospitals. In addition, there are several small and large dying industries, printing industries and storage battery manufacturing units in the city which directly or indirectly discharged their effluents into the river. Effluents from dying industries contained several compounds of metal, such as chromium, zinc, lead, mercury, etc. Whereas storage battery and printing effluents have high amount of lead and nickel compound which might be the possible reason for high level of metal content at this stretch. The range values of Cadmium in Citarum River are presented in Table 3.

Table 3.Range of Concentration of Cd at Various Sites

	Site	Concentration Cadmium (mg/L)		
		March	June	November
I	Cisanti Lake (Up Stream)	0	0	0
II	Cikapundung	0	0	0
III	Cisangkuy	0	0	0
IV	Cibeureum	0,01	0	0
V	Cibaligo	0,01	0	0
VI	Cimahi	0,01	0	0

Chromium hexavalen in Citarum River

Chromium has an atomic number of 24, an atomic weight of 51.996, consisting of four stable isotopes (^{52}Cr = 84%), and a density of 7.14 g cm^{-3}[1]. Crystalline Cr is steel-gray in color, lustrous, hard metal that has a melting point of 1,900ºC and a boiling point of 2,642ºC. It belongs to group VIb of the transition metals and in aqueous solution, Cr exists primarily in the trivalent (+3) and hexavalent (+6) oxidation states. Chromium, as well as Zn, is the most abundant of the "heavy metals" with a concentration of about 69 µg g^{-1}in the lithosphere [23].

In most natural waters at near neutral pH, Cr^{III} is the dominant form due to the very high redox potential for the couple Cr^{VI}/Cr^{III} [29]. Chromium (III) forms strong complexes with hydroxides. Rai et al. (1987) reported that the dominant hydroxo species were $CrOH^{2+}$at pH values 4–6, $Cr(OH)_3$at pH values from 6 to 11.5, and $Cr(OH)_4^-$at pH values above 11.5. The OH^- ligand was the only significant complexer of Cr^{III}in natural aqueous solutions that contained environmental concentrations of carbonate, sulfate, nitrate, and phosphate ions. The only oxidant in natural aquatic systems that has the potential to oxidize Cr^{III}toCr^{VI} is manganese dioxide. This compound is common on Earth's surface

and, thus, one can expect to find some Cr^{VI} ions in natural waters. The predominant Cr^{VI} species at environmental pH is CrO_4^{2-}[18]. The principal Cr^{III} solid compound that is known to control the solubility of Cr^{III} in nature is $Cr(OH)_3$. However, Sass and Rai (1987) have shown that $Cr/Fe(OH)_3$ has an even lower solubility. This compound is a solid solution and, thus, its solubility is dependent on the mole fraction of Cr; the lower the mole fraction, the lower the solubility is[32]. Most Cr^{VI} solids are expected to be relatively soluble under environmental conditions. In the absence of solubility-controlling solids, to Cr^{VI} aqueous concentrations under neutral pH conditions will primarily be controlled by adsorption/desorption reactions [30]. Under environmental conditions, iron oxides are the predominant adsorbents of chromate (to Cr^{VI}) in acidic to neutral pH range and oxidizing environments. The Cr concentration in average world river water is 0.7 µg L^{-1}[14] and that in ocean water is 0.21 µg L^{-1}[10].

Chromium occurs in nature mainly in the mineral chromite; Cr also occurs in small quantities in many minerals in which it replaces $Fe^{3+}$and Al^{3+}[12]. The metallurgy industry uses the highest quality chromite ore whilst the lower-grade ore is used for refractory bricks in melting furnaces. Major atmospheric emissions are from the chromium alloy and metal producing industries. Smaller emissions come from coal combustion and municipal incineration. In the aquatic environment, the major sources of Cr are electroplating and metal finishing industries. Hexavalent Cr^{VI} is a potent carcinogen and trivalent Cr^{III} is an essential trace element [20].

Chromium hexavalen data for river water at different locations during the study period are shown in Figure 1. The values of Chromium hexavalen in water ranged from 0.03 to 0.18 mg/L. The concentration of Chromium hexavalen in water exceeded the maximum permissible limit assigned by WHO [34] (0.05 mg/L) at almost all of the sites which reflected its pollutional status.

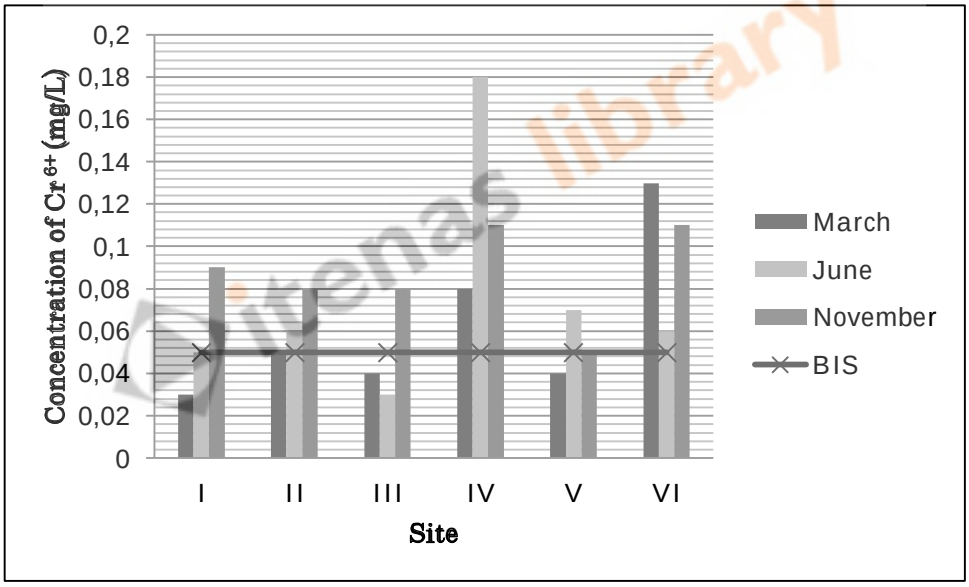

Fig. 1: Range of Concentration of Cr^{6+} at Various Sites

Zinc in Citarum River

Zinc (atomic no. 30) is a bluish-white, relatively soft metal with a density of 7.133 g cm^{-3}. It has an atomic weight of 65.39, a melting point of 419.6°C, and a boiling point of 907°C. Zinc is divalent in all its compounds and is composed of five stable isotopes (^{64}Zn = 49%) and a common radioisotope, ^{65}Zn, with a half-life of 245 days. It belongs to group IIb of the periodic table which classifies it as a heavy metal whose geochemical affinity is chalcophilic.

In freshwater, the uncomplexed Zn^{2+} ion dominates at an environmental pH below 8 whereas the uncharged $ZnCO_3$ ion is the main species at higher pH [18]. Complexing of Zn with SO_4^{2-} becomes important at high sulfate concentrations or in acidic waters. Hydrolysis becomes significant at pH values greater than 7.5; hydroxy complexes of $ZnOH^-$and $Zn(OH)_2$ do not exceed carbonate species at typical environmental concentrations of 15 µg/L for world stream water [14]. More recent data of [31] place the concentration of dissolved Zn in average world river water at 0.60 µg/L. Significant complexing with organic ligands may occur in stream and lake waters with highly soluble organic carbon concentrations. The concentration of Zn in ocean water is 0.39 µg/L [10], which is close to its value in world river water.

There are several factors that determine the relative abundance of dissolved and particulate Zn in natural aquatic systems. These include media pH, biogeochemical degradation processes that produce dominant complexing ligands, cation exchange and adsorption processes that control the chemical potential of solid substrates, and the presence of

occluded oxyhydroxide compounds [1], 1986). At pH values above 7, aqueous complexed Zn begins to partition to particulate Zn as a result of sorption onto iron oxyhydroxide. The clay mineral montmorillonite is particularly efficient in removing Zn from solution by adsorption [19].

The average Zn content of the lithosphere is ~80 µg/g and the most abundant sources of Zn are the ZnS minerals sphalerite and wurtzite and to a lesser extent smithsonite ($ZnCO_3$), willemite (Zn_2SiO_4), and zincite (ZnO) [31]. The smelting of nonferrous metals and the burning of fossil fuels and municipal wastes are the major Zn sources contributing to air pollution.

The values of zinc in river water at different locations during the study period are given in and Figure 2. Zinc was detected in most of the water samples. The values of zinc in water ranged from 0.0 to 1.44 mg/L. The result indicated higher concentration of zinc in river water. However, in case of water the concentration of zinc was within permissible limit as assigned by WHO[34] (0.05 mg/L).

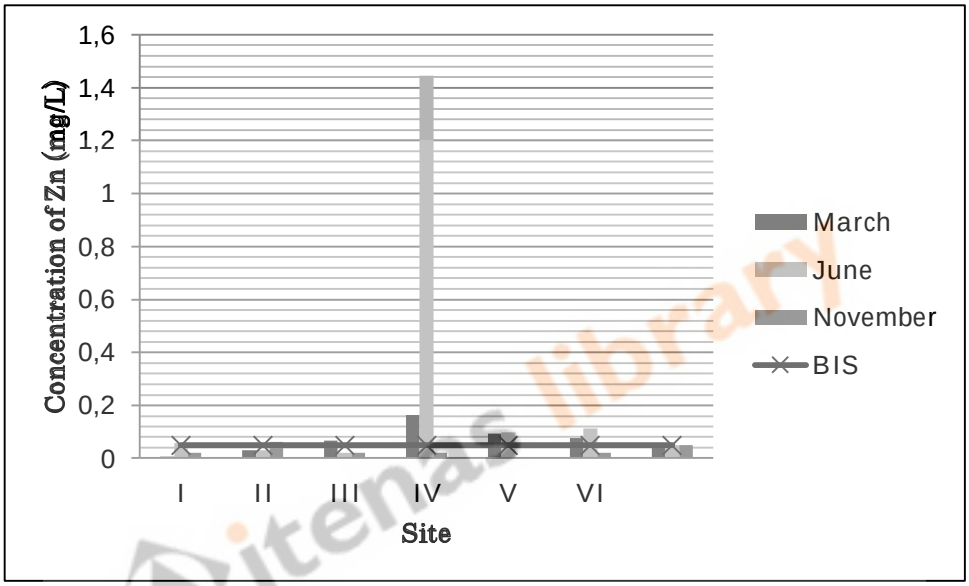

Fig. 2: Range of Concentration of Zn at Various Sites

Copper in Citarum River

Copper has an atomic number of 29, an atomic weight of 63.546, consists of two stable isotopes (^{63}Cu = 69.2%; ^{65}Cu = 30.8%), and has a density of 8.94 g cm^{-3}[33]. Metallic Cu compounds (sulfides) are typically brassy yellow in color while the carbonates are a variety of green and yellow-colored. The metal is somewhat malleable with a melting point of 1,356ºC and a boiling point of 2,868ºC. It belongs to group Ib of the transition metals and in aqueous solution Cu exists primarily in the divalent oxidation state although some univalent complexes and compounds of Cu do occur in nature [21]. Copper is a moderately abundant heavy metal with a concentration in the lithosphere of about 39 µg g^{-1}[23].

Chemical models for the speciation of Cu in freshwater [26] predict that free Cu^{2+}(aq) is less than 1% of the total dissolved Cu and that $Cu(CO_3)_2^2$and $CuCO_3$are equally important for the average river water. Leckie and Davis (1979) showed that the $CuCO_3$complex was the most important one near the neutral pH. At pH values above 8, the dihydroxo–Copper(II) complex predominates. The chemical form of Cu is critical to the behavior of the element in geochemical and biological processes [21]. Cupric Cu forms strong complexes with many organic compounds.

In the sedimentary cycle, Cu is associated with clay mineral fractions, especially those are rich in coatings containing organic carbon and manganese oxides. In oxidizing environments ($Cu–H_2O–O_2–S–CO_2$system), Cu is likely to be more soluble under acidic than under alkaline conditions [16]. The mineral malachite is favored at pH values above 7. Under reducing conditions, Cu solubility is greatly reduced and the predominant stable phase is cuprous sulfide (Cu_2S)[22]. In natural aquatic systems, some of the Cu is dissolved in freshwater streams and lakes as carbonate and organic complexes; a larger fraction is associated with the solid phases. Much of the particulate Cu is fixed in the crystalline matrix of the particles [17]. Some of the riverine reactive particulate Cu may be desorbed as the freshwater mixes with seawater. The biological cycle of Cu is superimposed on the geochemical cycle. Copper is an essential element for the growth of most of the aquatic organisms but is toxic at levels as low as 10 µg L^{-1}[21]. Copper has a greater affinity, than most of other metals, for organic matter, organisms, and solid phases [21], and the competition for

Cu between the aqueous and the solid phases is very strong. Krauskopf (1956) noted that the concentration of copper in natural waters, 0.8–3.5 µg L^{-1}[8], was far below the solubility of known solid phases. Davis et al. (1978) found that the adsorption behavior of Cu in natural systems was strongly dependent on the type and concentration of inorganic and organic ligands. Recent data of Gaillardet et al. (2003) placed the concentration of dissolved Cu in average world river water at 1.5 µg $L^{-1}$and that in ocean water at 0.25 µg L^{-1}[10].

The most common Cu minerals, from which the element is refined into the metal are Chalcocite (Cu_2S), Covellite (CuS), Chalcopyrite ($CuFeS_2$), Malachite and Azurite (carbonate compounds). It is not surprising that Cu is considered to have a chalcophillic geochemical affinity. In the past, the major source of Cu pollution was smelters that contributed vast quantities of Cu–S particulates to the atmosphere. Presently, the burning of fossil fuels and waste incineration are the major sources of Cu to the atmosphere and the application of sewage sludge, municipal composts, pig and poultry wastes are the primary sources of anthropogenic Cu contributed to the land surface [2].

The values of Copper in river water at different locations during the study period are given in and Figure 3. Copper was detected in most of the water samples. The values of Copper in water ranged from 0.0 to 0.08 mg/L. The result indicated higher concentration of Copper in river water. However, in case of water the concentration of zinc, it was within permissible limit as assigned by WHO [34] (0.02 mg/L).

Copper dissolved in the Citarum River comes mostly from industrial and municipal wastewaters. Concentrations of dissolved copper generally increase in the downriver direction, especially near urban centers. Some tributaries carry greater concentrations of copper than the main stem Citarum, but their influences on main stem concentrations seemed to be minimal. The transport of dissolved copper in the Citarum River varies directly with the water discharge. The most significant increases in the transport of dissolved copper occur at the confluences of the Citarum Rivers.

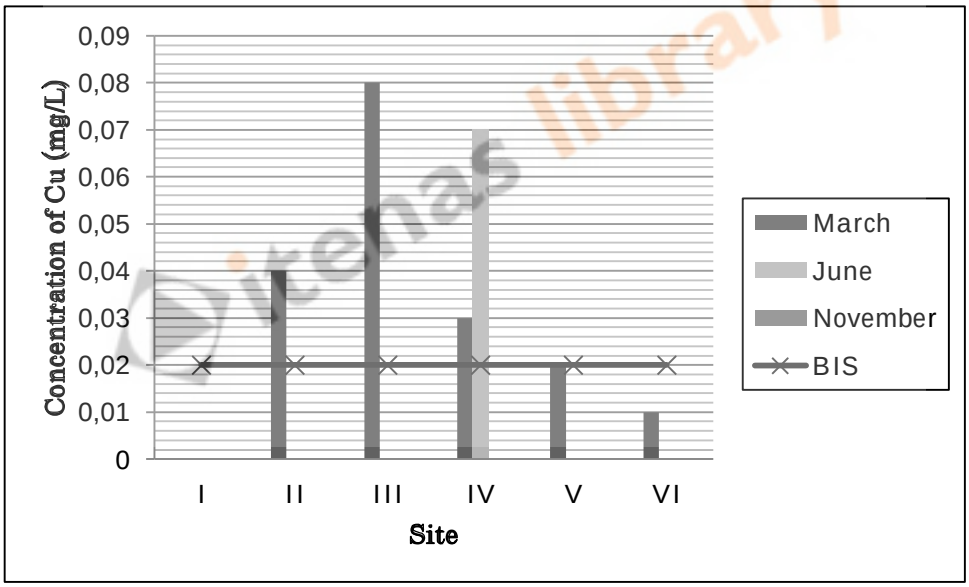

Fig. 3: Range of Concentration of Cu at Various Sites

The Fate of Metals in the Citarum River

The numerous studies of the heavy-metal water quality of the Citarum River that have been conducted over the last several years have emphasized mostly the water quality in specific regions of either the lower reaches of the river. However, our study assessed the heavy metal contamination through the full length of the Citarum River from Cisanti Lake to Cimahi. The water samples were collected during the entire study using proven sampling protocols. In addition, all samples were analyzed by one group of scientists in a single laboratory using state-of-the-art instrumentation and methodology. Heavy metals released into the Citarum River, both by natural processes and human activities, can be distributed among several different forms within the water environment. Metals can be either transported with the water and suspended sediment or stored within the riverbed bottom sediments. Heavy metals are transported as (1) dissolved species in the water, (2) suspended insoluble chemical solids, or (3) components of the suspended natural sediments. Metals dissolved in the water can exist as hydrated metal ions or as aqueous metal complexes with other organic or inorganic constituents. Water-insoluble inorganic (non-carbon-containing, except for carbonates) chemical solids, such as metal hydroxides, may be formed, as may organic (carbon-containing) chemical solids, such as those associated with compounds derived from the decay of living organisms. Both inorganic and organic solids can be transported with the water as individual entities or as chemical coatings on suspended sediments. In addition, mineral components of

suspended sediments themselves can contain heavy metals. Heavy-metal solids can also be stored in river-bottom sediments. Suspended sediments and metallic chemical solids are stored in riverbed sediment after they aggregate to form large, denser-than-water particles that settle from the water when the river's flow is not sufficient to keep them in suspension.

4. Conclusion

The study revealed that there was a considerable variation in the concentration of heavy metals in water samples at various sites. The variations might be due to the change in the volume of industrial and sewage being added to river at different sampling stations. In general, among different metals found in the river water were in range of: Cd (0.0 to 0,01 mg/L); Cr^{6+} (0.03 to 0.18 mg/L); Cu (0.0 to 0.08 mg/L); and Zn (0.0 to 1.44 mg/L). Some physic-chemical parameters which are dissolved oxygen, BOD_5, and COD were also estimated as they have direct or indirect influence on incidence, transport and speciation of the heavy metals. pH ranged from 6.2 to 8.5 at all locations, Dissolve oxygen ranged from 0.14 to 8.12 mg/L, Biochemical Oxygen Demand (BOD_5) ranged from 1 to 202 mg/L and Chemical Oxygen Demand (COD) ranged from 2 to 492 mg/L.

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