Screening of shallow groundwater in Aceh Besar and Banda Aceh Districts for contamination with heavy metals

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Abstract. Tsunami devastated many water infrastructures including the wells. Tsunami areas, land use (rural and urban areas) and land management (agriculture land and home garden) can be leading heavy metals in water quality. The purpose of this research is to investigate how the Tsunami rehabilitation efforts affected the water quality of shallow groundwater by measuring the count of heavy metals (mercury, cadmium and lead by Atomic Absorption Spectrophotometer during the rainy and dry season. Forty-eight water samples' of wells were collected to determine shallow groundwater from August 2007 to December 2007. The study includes interviews with the owners of the water facilities and sanitary inspection of shallow groundwater wells. The results show the presence Hg and most of Cd in well water are still below the regulatory acceptable limit by Ministry of Health R.I (2002). On the other hand, lead exceeds the regulatory acceptable limit.

Key words: Well, Heavy metals, Tsunami

Introduction

The earthquake and the following Tsunami devastated South Asia in December 2004 and especially Indonesia. It has caused remarkable problems such as social, economic and environmental aspects in some regions of Nanggroe Aceh Darussalam and Nias. Aceh Besar is one of the regions that have been impact hardest by Tsunami. One effect is the contamination of water that was caused by damaged sanitary infrastructure such as septic tanks, shallow groundwater, hand water canals. The water that was contaminated by Tsunami contains chemical and infectious materials that are dangerous for life.

According to Agency for Reconstruction and Rehabilitation (BRR) progress report (2006) in 2005, many donors and non-governmental organizations (NGOs) have focused on the provision of housing with limited investment in associated infrastructure. NGOs were encouraged to invest in housing construction without provision of basic services such as water supply, sanitation and electricity power. In 2006, a number of water supply projects were initiated, which are preparing and rehabilitating water supply that was damaged by Tsunami. Until October 2007, one hundred thousand houses have been built but sanitation and water supply systems were not completed. Some of new houses are vacant because the infrastructure projects have not caught up, leaving the house without water, electricity or adequate roads. Water sanitation is the most difficult part of construction. The well water was found still turbid.

Based on previous research by Mardiatno and Junun (2006) who reported that some water samples from shallow shallow groundwater have been contaminated by Tsunami; nevertheless, they partially still can be used for domestic purposes except for drinking water. Followed by Local Environmental Impact Management Agency (BAPELDALDA) and National Nuclear Energy Agency of Indonesia (BATAN) (2007) reported that a study of sites devastated by Tsunami showed water pollution in wells. It was caused by dangerous and poisonous material from Tsunami contamination that includes pathogenic microorganisms, as well as high contents of nitrate and heavy metals. They found 0.15mg/l for cadmium concentration. Elements cadmium (Cd), copper (Cu), and lead (Pb), the levels of heavy metals concentrations in the Tsunami mud exceeded the Ministry of Health Regulation RI.

The research was conducted in the Aceh Besar and Banda Aceh districts from August 2007 until December 2007 and aimed to determining how Tsunami rehabilitation efforts affected the water quality of shallow groundwater by measuring the concentration heavy metals, in rural and urban areas. The study includes bacteriological assessment of water samples, interviews with the owners of the water facilities and sanitary inspection of shallow groundwater wells. The sample points of shallow shallow groundwater were determined by simple random sampling method.

Materials and Methods

Description of xperimental Site, Time and Location

In this research, areas are referred to the Tsunami area and non-Tsunami area. Generally, all water bodies and water sources in the coastal areas and the other area were hit by the Tsunami and brought dangerous material and pollution, thus they did not function at all during some time after the disaster, both as water sources, water flow and city drainage as well as septic tanks were damaged.

The research has been conducted in fixed places which are damaged differently by the Tsunami in Banda Aceh and Aceh Besar District, to show the difference between urban and rural areas and the difference between agriculture land and home gardens. The research was done from last August 2007 to December 2007. The wells were selected randomly following many characteristics such as area, land use and land management. Twenty-four wells selected with repetition in dry season on August and rainy season on December. The selections of sample were done in the beginning of August, before the data collection was done. A total samples were 48 wells.

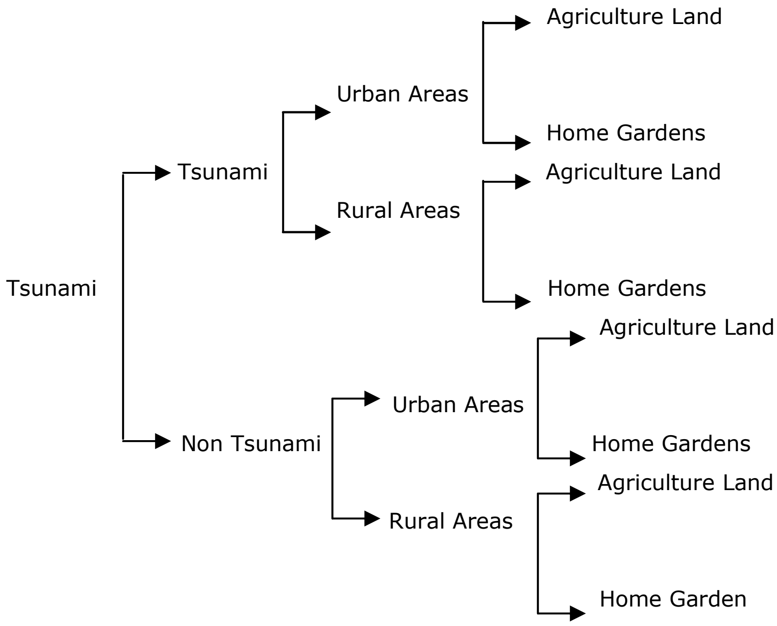

Figure 1. Selected characteristic places for sampling research

Based on Figure 1, the sample areas were selected by simple random sampling by taking three areas in each class according to the characteristics area needed. Then, for each area, the survey places were determinated by passing the main road of villages and numbering the place in a certain series. After that, three survey places were defined by randomly sampling. This research was conducted in two activities: firstly, samples were taken in the survey place and secondly, samples were analyzed in laboratory.

Collection of Sample

Before the water samples were collected, the interviews were carried out with the well owners to get general information about well's condition; characteristics of the household, the utilization of shallow shallow groundwater, depth of wells, and number of users. This information was needed to provide additional data for the description of the area.The minimum water amount of sample size (200 ml) was analyzed to know heavy metal contents especially cadmium, mercury and lead by Atomic Absorption Spectrophotometry

(AAS) at the Laboratory of the chemistry of natural science, Syiah Kuala University, in Nanggroe Aceh Darussalam, Indonesia.

Samples as water directly are analyzed, in contrast, if so solid samples must be leached or dissolved prior to analysis. Double beam apparatus was a very good ratio signal/noise. The optical system was tightened in such a way that it is protected against dust and corrosion. It has a flame atomization system, electrochemical atomization, hydride generator, auto sampler, data acquisition and processing soft. In order to analyze mercury, cadmium and lead a lamp is chosen that produces a wavelength of light that is absorbed by those element. Sample solutions are aspirated into the flame. If any ions of the given element are present in the flame, they will absorb light produced by the lamp before it reaches the detector. The amount of light absorbed depends on the amount of the element present in the sample. Absorbance values for unknown samples are compared to calibration curves prepared by running known samples.

Statistical Analysis

The statistical analysis was used to examine the data. This statistical test showed the effects of some independent variables in the research; tsunami and non tsunami area, urban and rural area, agriculture and home garden area.

The results of the interviews were explored by a descriptive statistics using SPSS 12.0 program. This analysis covered several questions asked to the owner including; shallow groundwater depth, shallow groundwater age and utilizations of shallow groundwater (drinking, cleaning, bathing, ets). The data of the shallow groundwater contamination was analyzed by ANOVA (Factorial design with 4 factors level) followed by a Tukey test to show the significant value by using SYSTAT version 5.0.

Results and Discussion

Land Use and Land Management

In Tsunami areas most of the surface water was turbid (59%) followed by clear, yellowish (33%) and only about 8% reach clear water surface. Some of the water had an unpleasant odor. According to American Public Health Association (1992) followed by Alley (2007) that turbidity could be caused by clay, sludge, domestic sewage, industrial sewage and may be associated with the presence of toxic compounds and pathogen. Although turbidity has no direct health effects, its presence was regarded the community as unsafe and therefore people of the community rejected the water for drinking. These conditions are related with those recorded by Anonymous (1996) that in general, the physical characteristics of water are not of direct public health concern, but they do affect the aesthetic quality of the water. Previous research carried out by Environment Service Program (ESP) (2006) showed that wells in Tsunami areas can be appeared brackish to saline and were adversely impacted by the Tsunami.

In the Tsunami area, most of the community did not use water from the well as drinking water; they bought bottled water with the cheaper price. Therefore, consumption of bottled drinking water is rapidly growing in the Tsunami area. Water was purified by using special equipment to filter the ground water. Yet, there is only limited availability of information about the microbiological safety and quality of bottled drinking water sold within in the Aceh community. Bottled drinking water does not receive any antibacteriological treatment; the risk of pathogen contamination is a public health concern. However, the community still used the wells for domestic purpose such as cooking (100%) followed washing and bathing (100%) and watering (53.33%). The effects of external factor like Tsunami affects on water quality were found to be complex.

Based on the interview that community in non-Tsunami area did not only use wells as the drinking water purpose (91.67%) but also for cooking (100%), washing and bathing (100%) and watering (53.33%). People used water from surface wells for drinking water in non Tsunami area due to the availability of the water well surface was 67% clear, followed 25% clear yellowish and only 8% present turbid.

According to the results of the interviews in rural and urban areas, that land use could be influence the quality of well water. The presence of night soil can lead to faecal contamination in water. Night soil was referred open field defecation by human faeces in the bush and plastic bags. In rural areas were found 50% night soil present and therefore no septic tank for sanitation system (50%). The correlation showed between distance sanitation and the presence soil night(r=-0.901). Negative correlation here means the closer sanitation distance to the well the higher soil night contamination. It indicated that if the area had night soil that means the sanitation infrastructure such as latrine was not available. On the other hand, in urban area mostly community had the toilet connected to a septic tank (100%).

The pollution of wells through shallow water by sanitation systems is a universal problem and is particularly severe for communities in Tsunami area. Many wells were polluted by seawater and by contamination from waste disposal and septic tank. Most of the problem sanitation effects on wells quality refer to septic tanks. Nevertheless, the other possibility was consideration such as poorly designed new wells; poor waste management can lead the contaminations of water

In the rural area, many manufactories/agribusiness enterprises were food processing such as tempe and tofu producer. Tempe and tofu are the product from soybean with fermentation by *Rhizopus* spp. Those microbes can contaminate the water and soil through waste disposal. Home industry needs participation from family members.

A number of small industrial enterprises were present in the urban area such as fuel depots, medicine treatments (Jamu), and serving car. The presence of those enterprises close to the wells was about 16.67 % for rural area and 41. 67% for urban area.

Presumably from all interview data showed, there was a risk of contamination with heavy metal to the well. Paliwal (1983) observed that increasing urbanization, cultivation and industrialization can caused higher microbial and chemical contamination in well water. Therefore, the examination of wells and land profile (other environmental) is a major public health undertaking.

Water Contamination by Heavy Metal

The data of heavy metal (mercury, cadmium and lead) were analyzed by ANOVA and followed post hoc Tukey test for was significant value of α =5%. The results for mercury concentrations were illustrated in Figure 2 and Figure 3.

Concentration of Mercury in Well Water

Figure 2 shows that there was an interaction between area and land use categories from all samples. The interaction shows that in non-Tsunami area there were no significant based on land use. However, in Tsunami area the urban area has lower Hg concentration than rural area. There was analyzed by ANOVA and obtained significant difference (P= 0.001) in mercury concentration between area and land use categories and followed post hoc Tukey test.

The concentration of mercury in wells was generally below the 1µg/l critical value quoted by Ministry of Health Regulation RI. The highest concentration of Hg was found in wells of the Tsunami affected rural areas that reached 0.584 µg/l. However, the lowest concentration of Hg was found in wells of Tsunami affected urban areas (0.043 µg/l). It was estimated that mercury from waste disposal and the location where taken sample close to a hospital. Medical products are reported to be sources of mercury in healthcare sector as well as in medical devices to support of health service to patient, pharmacy and chemical preservatives in vaccines, eye drops and cosmetics and thermometers, surgical equipment. Moreover, dentists always use dental amalgams for dental restorative. (Atjeh Student's of

Health Organization, 2008). These results are corroborated by Walhi (2005) that concentrations of mercury in wells in Tsunami areas were generally low.

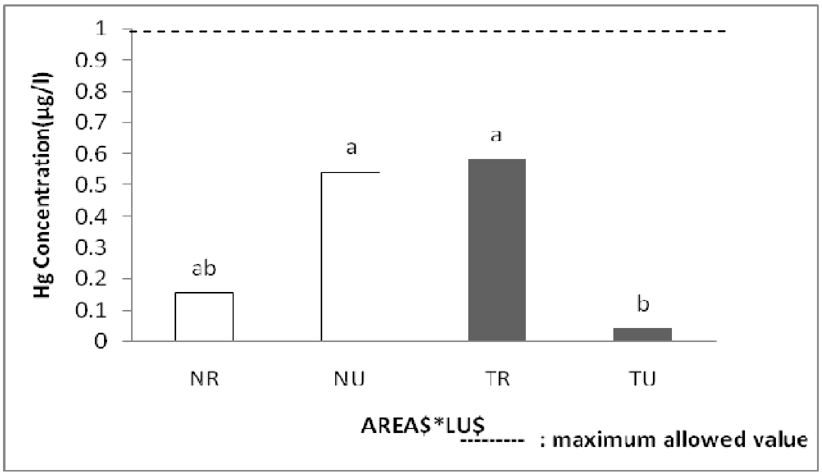

Figure 2. Interaction between area and land use in Hg concentration.
NR: Non-Tsunami Rural Area, NU: Non-Tsunami Urban Area, TR: Tsunami Rural area, TU: Tsunami Urban Area. .a, ab and b – different letters show statistically significant differences between locations ($P<0.05$).

Figure 3 shows that there were found interactions between area and land management. The interaction shows that in non-Tsunami areas there were no significant based on land management however in Tsunami area the agriculture area has higher Hg concentration than home garden area. There was analyzed by ANOVA and obtained was significant difference ($P= 0.034$) in mercury concentration between area and land management categories and followed post hoc Tukey test. The highest level of Hg concentration was detected in Tsunami agriculture (0.593 µg/l) while the lowest level was detected in Tsunami home garden (0.034 µg/l).

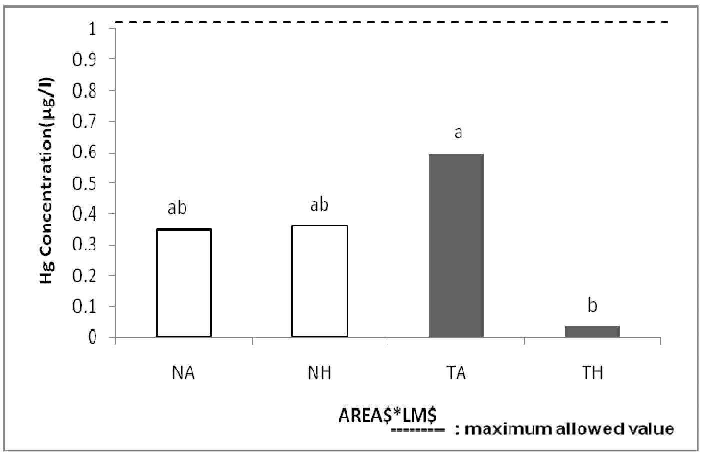

Figure 3. Interaction between area and land management in Hg concentration.
NA: Non-Tsunami Agriculture land, NH: Non-Tsunami Home Garden,
TA: Tsunami Agriculture Land, TH:Tsunami Home Garden.
a, ab and b – values with different letters show statiscally significant differences between locations ($P<0.05$)

Samples from wells located in Tsunami affected agriculture areas showed higher Hg concentrations than from wells in Tsunami affected home garden area. Agriculture areas using more more pesticide than that in home garden. Higher Hg concentration can also associated with the location of P.T. Semen Andalas cement factory through mercury in lime and coal about 5 km from the well. Most of the mercury emitted from cement kilns comes from limestone, the primary raw material in cement. Limestone contains varying amounts of mercury depending upon its geologic origin. A secondary source of cement plant mercury is coal, which is burned to achieve high temperatures for converting calcium and silicate oxides into calcium silicate (Anonymous, 2008).

According to Smeljakalova (2003), the higher heavy metal concentration, the lower distance from the source of the contamination. However, the entire sample had concentration of Hg below 1 µg/l (the critical value quoted by Ministry of Health Regulation RI).

Concentration of Cadmium in Well Water

The results from Figure 4 that cadmium concentration found many interactions among area, land use, land management and season. The samples were analyzed by ANOVA and obtained a significant difference (P= 0.003) in cadmium concentration and interaction among area, land use, land management and season categories and followed post hoc Tukey test point out significant value of α =5%.

Figure 4 shows that most of the samples had cadmium concentrations that were lower than 0.003 mg/l (the critical value quoted by Ministry of Health Regulation RI). The higher cadmium concentration was found in Tsunami urban home garden during rainy season (0.0036 mg/l). On the one hand, in non-Tsunami rural agriculture rainy area, non-Tsunami rural home garden area in dry season, non-Tsunami rural home garden area in rainy, and also Tsunami urban agriculture area in rainy season showed low cadmium concentrations (0 mg/l).

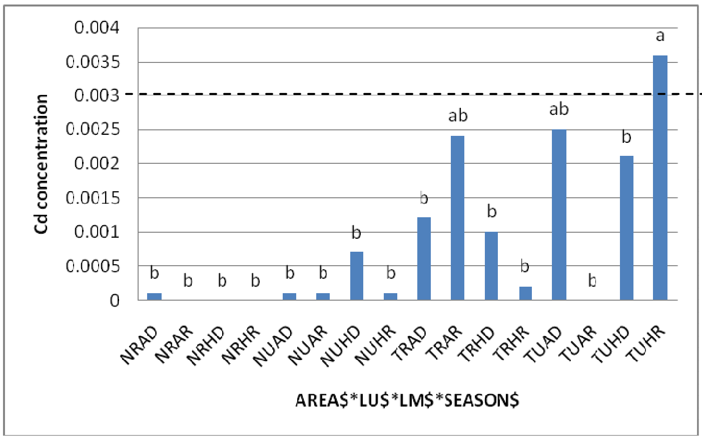

Figure 4. Interaction among area, land use, land management and season in Cd concentration. NRAD: Non-Tsunami Rural Agriculture Dry, NRAR: Non-Tsunami Rural Agriculture Rainy Area, NRHD: Non-Tsunami Rural Home Garden Dry, NRHR: Non-Tsunami Rural Home Garden Rainy, NUAD: Non-Tsunami Urban Agriculture Dry:NUAR: Non-Tsunami Urban Agriculture Rainy, NUHD: Non-Tsunami Urban Home Garden Dry, NUHR: Non-Tsunami Urban Home Garden Rainy: TRAD: Tsunami Rural Agriculture Dry, TRAR: Tsunami Rural Agriculture Rainy, TRHD: Tsunami Rural Home Garden Dry, TRHR: Tsunami Rural Home Garden Rainy, TUAD: Tsunami Urban Agriculture Dry, TUAR: Tsunami Urban Agriculture Rainy, TUHD: Tsunami Urban Home Garden Dry, TUHR: Tsunami Urban Home Garden Rainy. A, ab and b – different letters show statiscally significant difference between location (P<0.05)

Climate influence the effect of contaminants like heavy metals, faecal coliform. Higher cadmium concentrations during the rainy season area probably due to rainfall and run off into the wells. It was estimated that sources of cadmium contamination in wells

Tsunami urban home garden were increased from the debris that brought from the Tsunami wave, oil and pollutants from road surfaces. Walhi (2005) reported that in Tsunami areas the cadmium levels in wells were above the detection limit (0,15mg/l).

Concentration of Lead Water in Well Water

Figure 5 showed the interaction among land use, land management and season. The samples were analyzed by ANOVA and it pointed out a significant difference (P= 0.007) in lead concentration and interaction among land use, land management and season categories and followed post hoc Tukey test for was significant value of α =5%.

The interaction shows that in rural areas exist no significant which based on land management and season. In contrast, in urban areas were pointed out a significant which based on land management with urban home garden in rainy season which included also higher lead concentration than in urban agriculture in rainy season.

Based on mean samples interaction among land use, land management and season were exceeded 10 µg/l (the critical value quoted by Ministry of Health Regulation RI). The highest lead concentration was found in urban home garden rainy season (24µg/l) while the lowest was found in rural home garden area in rainy season (12µg/l).

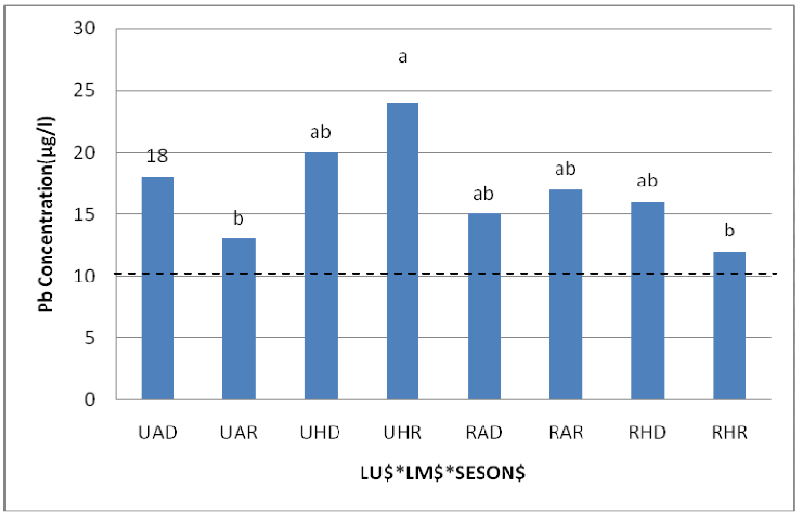

Figure 5. Interaction between land use and land management and season in lead concentration.UAD: Urban Agriculture land Dry, UAR: Urban Agriculture land Rainy, UHD: Urban Home garden area Dry, UHR: Urban Home garden Rainy, RAD: Rural Agriculture land Dry, RAR: Rural Agriculture land Rainy, RHD: Rural Home garden Dry, RHR: Rural Home garden Rainy. a, ab and b – different letters show statistically significant difference between location (P<0.05)

The high lead concentration in wells may be attributed to the characteristic area where the taken sample. The informations based on the interview with respondents, informations obtained characteristic about the location. Baiturahman was one location, with low laying area which is formed like a pond, where samples were taking. This area was flooded for a long time after the Tsunami. Lead contamination occurred because of lead plumbing system (Goldberg, 1974). In the surrounding of the sample site, there was the biggest hotel building devastated by Tsunami, debris waste, and accumulated waste of stuff and materials belonging to the people such as old batteries, car, smoke and Tsunami mud in the pond (slope area). Lead contamination can increase the run off which can enter the well due to following of heavy rains.

In contrast, non-Tsunami agriculture area was found still higher lead content. It was estimated that lead concentrations present due to natural sources. None available specific information's can cause lead contamination in these wells. Specific investigations are needed to know why contamination lead might have occurred.

Previous research by Walhi (2005) showed that in Nanggroe Aceh Darussalam, mud from of occurrence of earthquakes and the Tsunami was abundant in heavy metal content. Followed by Environment and Mineral Resource Sector (2005) that the direct assessments in the field, the mud pollution caused by the Tsunami occurred mostly in the northern area, especially in Banda Aceh and its surroundings. The results of observation of a number of heavy metal parameters, such as Cadmium (Cd), Copper (Cu), and Lead (Pb) showed that the heavy metal content in the Tsunami mud exceeded the determined limit. Therefore, the sources and causes of the mentioned heavy metal pollution have not yet been determined, thus further research is required.

It could be concluded that all heavy metals contamination from the results may occur naturally, or because of human activity. Naturally referred to Tsunami factor, in contrast, human activity referred to land use (rural and urban activity) and land management (agriculture land and home garden).

Conclusions

All results from interview and heavy metal analyzing can be concluded:

Heavy metals like mercury shows that in non-Tsunami area there were no significant which based on land use however in Tsunami area the urban area had lower Hg concentration than rural area. It is also found out that the interaction that in non-Tsunami areas were indicated no significant which based on land management. However, in tsunami areas the agriculture areas have a higher Hg concentration than home garden areas. Most of the samples had cadmium concentrations that were lower than 0.003 mg/l (the critical value quoted by Ministry of Health Regulation RI). Furthermore, based on mean samples interaction among land use, land management and season were exceeded 10 µg/l (the critical value quoted by Ministry of Health Regulation RI).

The site with different land profiles has different characteristic of well water quality. Each type of area (Tsunami affected), land use (rural and urban) and land management (agriculture and home garden), will have its own specific impact, usually directly on ecosystem or indirectly on well water.

Acknowledgements

I wouldlike to express my great appreciation to Prof. Dr. med. Uwe Gross and Dr.Ronald F. Kuehne.

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