

Appendix

Procedure of pollution potential area establishment and origin evaluation of groundwater arsenic

1. Establishment of potential areas for groundwater arsenic (As) pollution

- 1.1 According to the results of worldwide previous investigations on As-polluted groundwater, the geochemical characteristics of As-polluted groundwater and sedimentary can be summarized as follow:
 - 1.1.1 Most of Long-term groundwater As concentrations exceeds Groundwater Pollution Monitoring Standards: Due to the slow velocity of groundwater flow, the variation of groundwater As concentration is slight within the undisturbed groundwater As potential area. Groundwater As concentrations over the years mostly exceeded Groundwater Pollution Monitoring Standards.
 - 1.1.2 Relatively higher As contents are found in geological sediments: due to great As contents deposited in geological sediments, and is the main source of As-polluted groundwater, thus the monitoring wells with higher As concentration groundwater, their screens' interval sediments also have higher As concentration. Generally, background As concentrations of non-polluted sediments are mostly lower than 20 mg/L.
 - 1.1.3 Geological sediment is mostly composed of silty clay with fine-sand: The fine sediment with silty clay facilitates for reduction reaction and As enrichment in subsurface environment. The sediment profile of geological drilling by setting the monitoring wells can be adopted for evaluating the potential of groundwater As pollution.
- 1.2 According to the results of periodical groundwater quality monitoring,

the catchments with aforementioned hydrogeological characteristics in Taiwan are Choushui river alluvial fan, Chianan plain, Pingtung Plain, Lanyang Plain. The groundwater As pollution potential areas of these 4 catchments are shown in Appendix Table 1.

- 1.3 If the groundwater As concentration is detected and exceeds the Groundwater Pollution Monitoring Standards in aforesaid potential areas, the emergency measure is not necessary. The origin of groundwater As then can be referred to hydrogeological conditions and environmental background.
- 1.4 The aforesaid groundwater As pollution potential areas should be adjusted based on the results of periodical groundwater quality monitoring.

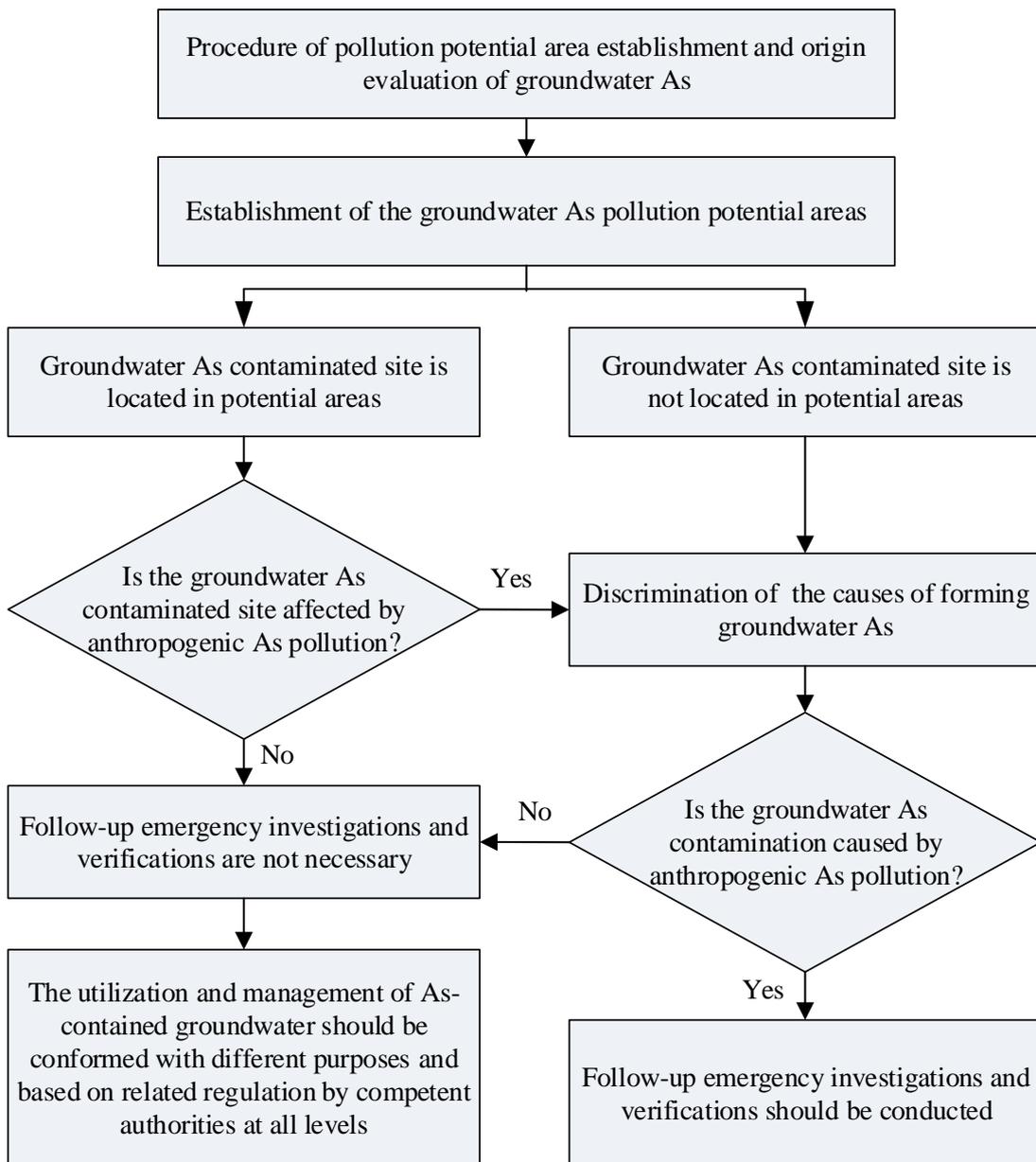
2. Evaluating the origin of groundwater As

- 2.1 Origin of groundwater As should be investigated under the following situations (Appendix Figure 1):
 - 2.1.1 Groundwater As contaminated sites are not located in aforesaid potential areas.
 - 2.1.2 Groundwater As contaminated sites are located in aforesaid potential areas and maybe affected by external As pollution.
- 2.2 Under the aforementioned situations, the procedure of evaluating the origin of groundwater As should be considered (Appendix Figure 2) to discriminate the causes of forming groundwater As. The procedure includes at least following steps:
 - 2.2.1 The hydrogeological characteristics and human activities of the contaminated site should be collected. The investigation coverage of groundwater As pollution should be established.
 - 2.2.2 The groundwater levels variation, groundwater quality data, geological characteristics of the existed wells around the contaminated site should be collected to preliminary evaluate the possibility of reaching for reasons not attributable to external pollution.

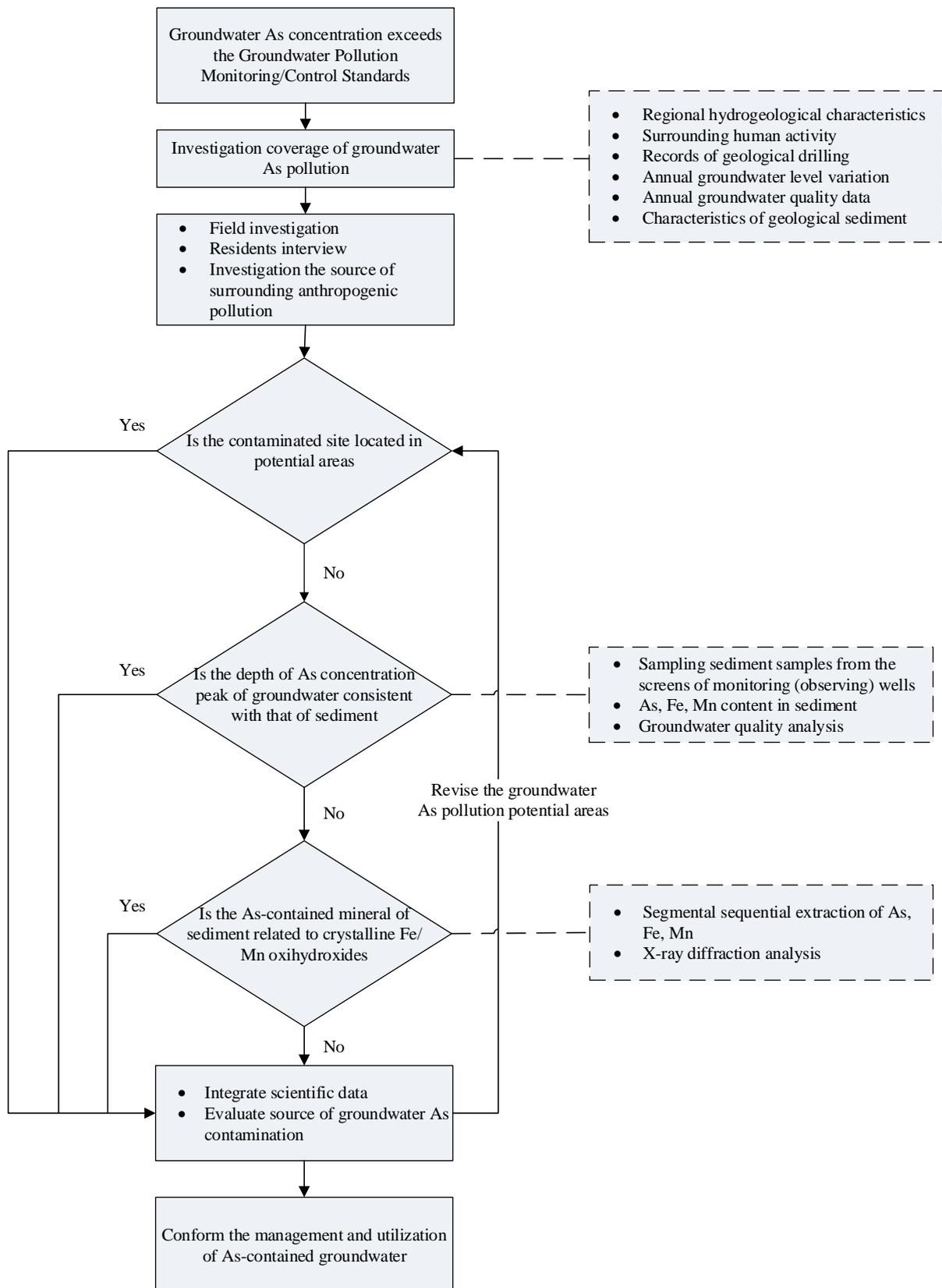
- 2.2.3 The field investigation and residents interview should be conducted to evaluate the possibility of the source of surrounding anthropogenic pollution.
- 2.2.4 According to the aforementioned groundwater As pollution potential areas, if the contaminated site is located in potential areas and is reached for reasons not attributable to external pollution, then the follow-up emergency investigations and verifications are not necessary.
- 2.2.5 If the contaminated site is not located in potential areas, it needs to collect the groundwater and sediment samples from the screens of monitoring wells to conduct the analysis of total As-content; in addition, if the depth of As concentration peak of groundwater is consistent with that of sediment, and is reached for reasons not attributable to external pollution, then the follow-up emergency investigations and verifications are not necessary.
- 2.2.6 If the depth of As concentration peak of groundwater is not consistent with that of sediment, the segmental sequential extraction and X-ray diffraction analysis are necessary to confirm the As-contained mineral phases, and Fe/Mn minerals; in addition, if it relates to crystalline Fe/Mn oxihydroxides, and are reached for reasons not attributable to external pollution, then the follow-up emergency investigations and verifications are not necessary.
- 2.2.7 Emergency investigations and verifications of soil and groundwater are necessary if the As-contained mineral phases of sediment are not related to crystalline Fe/Mn oxihydroxides to verify the source of groundwater As contamination.
- 2.3 According to 1.4, 2.2.5~7 in this appendix, the groundwater As pollution potential areas should be revised based on the results of periodical groundwater quality monitoring or investigations of groundwater As sources.

3. Management and utilization of As-contained groundwater

The utilization of As-contained groundwater in the groundwater As pollution potential areas (Appendix Table 1) should be conformed with different purposes. The appropriate treatment of water quality purification and depths and amounts of groundwater pumping should be proposed by competent authorities at all levels according to related water quality standards and groundwater demands.



Appendix Figure 1 Procedure of pollution potential area establishment and origin evaluation of groundwater arsenic



Appendix Figure 2 Procedure of evaluating the origin of groundwater As

Appendix Table 1 Groundwater As pollution potential areas of Taiwan

Catchment	County/City	Township/ District	Village
Choushui river alluvial fan	Changhua County	Dacun	Dacun, Daqiao, Jiayi, Pinghe, Tianyang, Cunshang, Nanshi, Meigang, Jiadong, Gongqi, Huangcuo, Xinxing, Guogou, Fuxing, Baitang
	Changhua County	Yongjing	Wubian, Yongxing, Dongning, Lunzi
	Changhua County	Xiushui	Andong, Anxi, Xiushui, Jinxing, Xiaxi, Mxing, Zhuangya, Zengcuo, Yixing, Fu'an, Heming
	Changhua County	Shetou	Xiehe, Nandi, Nanya, Xincuo, Qiaotou
	Changhua County	Fenyuan	Dapu, Zhulin, hekou, Fenyuan, Jinfen, Fengkeng, Jiushe
	Changhua County	Huatan	Sanchun, Zhongkou, Zhongzhuang, Wende, Beikou, Yongchun, Baisha, Yanzhu, Huatan, Jindun, Changsha, Changchun, Nankou, Lunya, Liucuo, Qiaotou, Wandong, Wanya
	Changhua County	Yuanlin	Sanduo, Sanhe, Sanxin, Santiau, San'ai, Sanyi, Sanqiao, Daming, Dapu, Darau, Zhongshan, Zhongyang, Zhongzheng, Renmei, Chushui, Minsheng, Guangming, Xidong, Heping, Dongbei, Donghe, Lincuo, Nanping, Nanxing, Lunya, Huilai, Xinsheng, Xinxing, Yuantan, Gouzao, Wannian, Liming
	Changhua County	Puxin	Taiping, Wazhong, Wabei, Wanan, Dongmen, Youche, Jingkou, Yimin
	Changhua County	Lukang	Dongqi, Yangcuo, Pulun, Haipu, Caozhong, Dingcuo, Zhao'an, Liaucuo
	Changhua County	Changhua City	Pinghe, Yanhe, Dongfang, Nan'an, Nanmei, Nanxing, Citong
	Changhua County	Fuxing	Dalun, Fanpo
	Yunlin County	Kouhu	Xialun, Shuijing, Chenglong, Houcuo, Pubei, Lunzhong, Lundong, Wubei, Wunan, Keliau, Gangxi, Gangdong, Hukou, Hudong, Guogang, Taizi, Xiecuo
	Yunlin County	Dapi	Dade, Beizhen, Xizhen, Yiran, Xing'an
Yunlin County	Yuanchang	Lunan, Xinji	

Yunlin County	Shuilin	Tucuo, Dashan, Dagou, Shanjiu, Shuibe, Shuinan, Jianshan, Xijing, Chegong, Songzhong, Songbei, Songxi, Houliu, Chunpu, Haipu, Shunxing, Wendi, Xiqian, Wanxing, Fanshu, Qiongpu, Suqin, Wanxi, Wandong
Yunlin County	Beigang	Shuipu, Haushou, Fuchau, Shujiau
Yunlin County	Sihu	Sanxing, Neihu, Sihu, Yangdiao, Lindong, Lincuo, Shihu, Feisha, Feidong, Lunbei, Lunnan, Luchang, Huxi, Huliao, Xinzhuang, Xiwei, Xidi, Guanggou, Caicuo
Yunlin County	Dongshi	Simei, Annan, Changnan, Dongbei, Dongnan, Fuxing, Chenghai, Jialong, Longtan
Yunlin County	Mailiao	Haifeng
Yunlin County	Taixi	Shanliu, Wugang, Wulang, Niucuo, Yongfeng, Guanghua, Hefeng, Quanzhou, Haikou, Haibe, Hainan, Wengang, Fuqi, Xiding, Taixi
Chiayi County	Dongshi	Xiayi, Haipu Vil, Fulai, Dingyi, Weitan, Gangkou, Xixia, Niausong, Longgang, Aogu
Chiayi County	Liujiu	Gongchang, Gulin, Yongxian, Zhuben, Bengshan, Yuliao, Suandong, Suantou, Wanbei, Wannan
Chiayi County	Dalin	Sancun, Sanhe, Shanglin, Zhonglin, Neilin, Pinglin, Jilin, Xilin, Xijie, Minghe, Minghua, Donglin, Pailu, Yihe
Chiayi County	Xikou	Bencuo, Miaulun, Pingding, Linjiu, Liugou, Meibe, Meinan, Chailin, Youxi, Youdong, Xibe, Xixi, Xidong, Diexi
Tainan City	Central	All
Tainan City	North	All
Tainan City	West	All
Tainan City	North	All
Tainan City	South	All
Tainan City	Anping	Wenzhu, Shimen, Anzhong, Vi Ximen, Miaushou, Jincheng, Xiaoqian, Haixing, Pusa
Tainan City	Annan	Sicao, Anxi, Xingfu, Qingcao, Chengxi, Chengnan, Haixi, Haidian, Hainan, Yuanzhong, Lixiang, Lu'er, Xidong, Xiqian, Xiangong, Yantian
Tainan City	Qigu	Qigu, Shifen, Sangu, Datan, Zhongliu, Yucheng, Xiliao, Chengnei, Hougang, Dingshan, Xinan, Dujia, Longshan, Yancheng
Tainan City	Xiaying	Dapi, Renli, Hejian

Tainan City	Rende	Taizi
Tainan City	Beimen	Jinhu、Shuangchun
Tainan City	Yongkang	Dawan, Wangxing, Beiwan, Yongkang, Xishi, Xiwan, Dongwan, Nanwan, Puyuan, Wuzhu, Kunshan, Xinshu, Niausong, Longtan
Tainan City	Xigang	Xigang, Gangdong
Tainan City	Jiali	Sanxie, Zilong, Anxi, Jiahua, Haicheng, Dingkuo, Xizhou, Jiafu, Zhangzhou, Xinghua, Yingding, Lihua
Tainan City	Guantian	Balin, Dongzhuang, Dutou
Tainan City	Houbi	Shi'an, Zhuxin, Houkuo, Dingchang, Jingliu, Xinjia
Tainan City	Liuying	Danong、Guoyi
Tainan City	Jiangjun	Sanji, Renhe, Beipu, Yushan, Xihe, Xihua, Zhongxing, Changrong, Bauyuan, Jiangfu, Jianggui, Jiachang, Kunming, Kunshen
Tainan City	Madou	Xiaopi, Beishi, Youche, Pitou Zhuangli, Xinjian, Zhuanjing, Xingnong, Longquan
Tainan City	Shanhua	Xiaoxin, Liufen, Liude, Wenchang, Niuzhuang, Guangwen, Xiguan, Zuoja, Dongchang, Donglong, Nangan, Hujia, Ximei, Jiabei
Tainan City	Xinhua	Shanjia, Taiping, Beishi, Quanxing, Xiexing, Fengkou, Lunding, Fengrong
Tainan City	Xinshi	Sanshe, Dazhou, Daying, Yongjiu, Shenei, Gangqian, Xinshi, Xinhe, Fenghua
Tainan City	Xuejia	Hongjia, Dingzhou
Tainan City	Guiren	Damiau, Xipu, Mamiau
Tainan City	Guanmiao	Pitou
Tainan City	Yanshui	Xiazhong, Dazhuang, Jingshui, Houzhai, Suncuo, Tongliu, Jiuying, Huanya
Chiayi City	West	All Dist.
Chiayi City	East	All Dist.
Chiayi County	Taibao	Taibao, Tianwei, Anren, Dongshi, Qiantan, Houzhuang, Houtan, Chunzhu, Pixiang, Lunding, Meipu, Maliau, Gangwei, Xinpi, Guogou, Jiupi
Chiayi County	Shuishang	Dalun, Zhonghe, Guoxing, Cuxi, Tugou
Chiayi County	Budai	Yong'an, Guangfu, Haumei, Jiangshan, Kaushi, Daijiang, Fuxing, Caipu, Xinmin, Xincen
Chiayi	Minxiong	Dinglun, Fuquan, Liauding, Fongshou, Zhenbei

	County		
	Chiayi County	Zhongpu	Hemu, Hexing, Fushou
	Chiayi County	Puzi	Meihua, Xinzhuang, Dejia
	Chiayi County	Lucao	Sanjiau, Xiama, Xiatan, Guangtan, Zhushan, Xijing, Songzhu, Houjue, Houliu, Shijia, Chongliu, Ludong, Lucao, Bitan, Fongchou
	Chiayi County	Yizhu	Zhongping, Beihua, Pingxi, Xigu, Guanhe, Guanshun, Dongguo, Dongrong, Houzhen, Piqian, Xindian, Xinfu, Xizhou, Touzhu, Longjiau
	Kaohsiung City	Yong'an	Yong'an, Bauning, Xingang, Yantian
	Kaohsiung City	Gangshan	Dazhuang, Daliau, Ren'ai, Baimi, Shitan, Zhuwei, Xierong, Gangshan, Houxie, Weisui, Huagang, Jiafeng, Jiaying, Shoutian, Fuxing, Taishang, Liucuo, Tandi
	Kaohsiung City	Alian	Yuku, Gangshan, Fu'an, Ganghou
	Kaohsiung City	Qieding	Dading, Baiyun, Guangding, Jiding, Hexie, Bauding, Qilou, Jia'an, Jiading, Jiatai, Jiafu, Jiale, Jiasi
	Kaohsiung City	Ziguan	Zhonglun, Zixin
	Kaohsiung City	Hunei	Zhongxian, Zhongxing, Haishan, Yixian, Yecuo, Liujia
	Kaohsiung City	Luzhu	Sanye, Xiakeng, Zhuyuan, Shedong, Dingliu, Xinda, Yalieu
	Kaohsiung City	Qiaotou	Zhongqi, Shihe, Shilong, Shifeng, Jiabei, Jianan, Baishu, Xilin, Yulieu, Donglin, Dingyan, Bixiu, Xinzhuang, Desong, Qiaotou
	Kaohsiung City	Yanchao	Jiausu
	Pingtung County	Jiadong	Liugen, Jiadong, Wenfeng, Yanwen, Laijia
	Pingtung County	Donggang	Datan
	Pingtung County	Fangliao	Dazhuang, Dili, Donghai, Xinlong
	Pingtung County	Linbian	Renhe, Shuili, Yongle, Tiancuo, Guanglin, Chifen, Zhen'an

	Yilan County	Wujie	Erjie, Sanxing, Shangsi, Daji, Zhongxing, Wujie, Sijie, Chengxing, Lize, Xiehe, Jixin, Fuxing
	Yilan County	Dongshan	Sanqi, Daxing, Taihe, Dongshan, Anping, Dongcheng, Wuyuan, Nanxing, Zhenzhu, Xianghe, Bucheng
	Yilan County	Zhuangwei	Meifu, Xinnan
	Yilan County	Yilan City	Dadau、Zhongshan、Zhongzheng、Wenhua、Beimen、Beijin、Minsheng、Minzu、Minquan、Ximen、Xiaolian、Hemu、Shengping、Dongmen、Nanmen、Jianjun、Siyuan、Fuguo、Shennong、Jiaubai、Meizhou、Fuxing、Jinshi、Ewang、Xinmin、Xinsheng、Qinghe
	Yilan County	Yuanshan	Yonghe、Tongle、Shangde、Zhenshan、Yuanshan、Huihau、Toufen
	Yilan County	Jiaoxi	Erjie, Yutian, Yuguang
	Yilan County	Luodong	Daxin, Zhulin, Dong'an, Xinyi, Xinqun
	Yilan County	Su'ao	Yongguang, Yongchun, Yongle, Cunren, Yueming, Chang'an, Gangbian, Xincheng, Shenghu, Aiding, Longde Vil, Subei, Suxi, Sudong, Sunan

The groundwater As pollution potential areas are evaluated by geostatistics method. The average groundwater As concentrations investigated by Water Resource Agency (2001-2011) and Environmental Protection Administration (2001-2011) are adopted for estimating the distribution of contaminated probability >75%, which the concentrations exceed the Groundwater Pollution Monitoring Standards Category 1 (0.025 mg/L).